Negative Emission Technologies and Climate Cooperation*

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Abstract

Negative Emissions Technologies (NETs) — a range of methods to remove carbon dioxide from the atmosphere — are a crucial innovation in meeting temperature targets set by international climate agreements. However, mechanisms that undo the adverse consequences of short-sighted actions (such as NETs) can fuel substitution effects and crowd out virtuous behaviors (e.g., mitigation efforts). For this reason, the impact of NETs on environmental preservation is an open question among scientists and policy-makers. We model this problem through a novel *restorable common-pool resource game* and use a laboratory experiment to exogenously manipulate the key features of NETs and assess their consequences. We show that crowding out only emerges when NETs are surely available and cheap. The availability of NETs does not allow experimental communities to either conserve the common resource for longer or accrue higher earnings and makes the earnings distribution more unequal.

Keywords: Climate Crisis, Environmental Sustainability, Carbon Dioxide Removal, Common-Pool Resource, Free-Rider Problem, Laboratory Experiment
JEL Codes: C92, H41, Q55

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1 Introduction

To stabilize global temperature within safe limits, we must reach net zero global carbon emissions.[1] Meeting this target will require extensive mitigation efforts in most sectors. It will also require deploying *negative emission* or carbon dioxide removal (CDR) technologies to compensate for emissions from hard-to-abate sectors and developing countries that might need more time to transition to clean technologies. In the short term, mitigation efforts will play a major role, with negative emission technologies serving only as a complementary instrument. In the medium term, however, when economies will be mostly decarbonized, negative emissions technologies will be crucial. Their potential significance lies in their capacity to counteract past excessive cumulative emissions. Indeed, achieving net negative (rather than simply net zero) global emissions may be eventually necessary to offset the accumulation of excessive emissions in the atmosphere (Riahi et al. 2022).

Negative Emissions Technologies (NETs) include various biological, chemical, and geochemical processes capable of removing carbon dioxide from the atmosphere and storing it in soils, materials, geological formations, and oceans. These methods range from long-time known and widely used nature-based practices, such as afforestation and reforestation, to less mature and more ambitious solutions relying on enhanced natural processes or carbon capture and storage technologies, which operate either directly from the air or at plants producing electricity with biomass.

While NETs' role will be critical in solving the climate change crisis, their significance is conditional on several factors. First, the feasibility of their large-scale deployment is still debated within the scientific community (IPCC 2022, Minx et al. 2018, Fuss et al. 2018). Depending on the technologies and the evolution of climate on Earth, several unanticipated issues may arise. For example, while afforestation and reforestation are considered among the most cost-effective methods for large-scale carbon dioxide removal, their potential could be significantly diminished by climate change: as forests near critical resilience thresholds—particularly in biomass-rich regions like the Amazon—their ability to recover may weaken. Additionally, disturbances such as fires, windfall, and pest outbreaks are expected to become more frequent and severe, further compromising forest resilience (Windisch et al. 2023). Second, monitoring and verifying the long-term carbon dioxide sequestration poses a governance

[1] See Lacis et al. 2010 on the relationship between greenhouse gas concentration in the atmosphere (especially carbon dioxide) and global temperatures over history; Pachauri et al. 2014 and Mann et al. 2017 on anthropogenic climate change; Field et al. 2014 on the severe negative consequences of a changing climate on humans and their economic activities. In 2015, 196 countries pledged to hold the increase in the global average temperature to well below 2°C compared to pre-industrial levels through the legally binding Paris Climate Agreement. To achieve this goal, emissions need to be urgently and drastically reduced and reach the net zero target early in the second half of the century (Rogelj et al. 2018).

challenge, as institutions must be created to guarantee the long-term permanence of these stocks (Sovacool et al. 2023). Third, carbon dioxide removals might not be able to entirely undo the effect of past carbon emissions if the temporary excess of emissions and the resulting overshooting of temperatures has triggered a tipping point, kick-starting an irreversible natural process (Drouet et al. 2021).

Finally, and most critically from a social sciences perspective, negative emissions technologies present a significant moral hazard problem. If, instead of being perceived as a complement to immediate emission reductions, they are considered a substitute for these economically and politically costly short-term actions, they could ultimately delay or crowd out current emissions abatement efforts. This *risk of mitigation deterrence* poses a serious threat to our ability to limit global warming, as postponing emissions reductions may result in irreversible damage. The danger is further amplified by the technical and implementation challenges associated with NETs. Misjudging the uncertainty of their future availability, and failing to treat removal technologies and emission reduction policies as independent, additive strategies, risks conflating their roles. This misunderstanding could forfeit a potential reduction in end-of-century warming by as much as 0.5°C (Grant et al. 2021). Additionally, neglecting the substitution effects and other unintended consequences of large-scale NET deployment could lead to an underestimation of the required CO2 mitigation efforts, potentially resulting in net CO2 additions equivalent to a further temperature increase of up to 1.4°C (McLaren 2020).

In this paper, we explore the role and risks of introducing mechanisms designed to reverse the consequences of past harmful actions. To do so, we model the substitution problem associated with negative emissions technologies using a novel adaptation of the classic dynamic common pool resource game, a well-established framework for studying issues related to natural resource use and conservation. In the standard version of this game, a group of players share access to a finite resource, such as a fishery, groundwater basin, or forest; in each period of an infinite horizon, each player decides how much to extract from the shared resource; if total extraction is moderate, the resource regrows to its initial level and players can harvest it again in the next period; if, instead, total extraction is excessive, the shared resource is irreversibly exhausted, causing the game to end. The analogy to the real-world problem is straightforward: overexploiting natural resources and engaging in high-emission activities may provide economic benefits in the short term but ultimately harm long-term well-being and sustainability. Conversely, adopting conservative resource use and committing to low-emission targets could impose short-term costs on individuals but yield collective benefits by ensuring community subsistence in the medium to long term—provided that all members commit to and maintain a coordinated, virtuous course of action.

To study the role of negative emission technologies, we conduct a laboratory experiment to investigate behavior in a novel environment: the *restorable* common-pool resource game. In this game, when collective extraction is excessive, a restoration technology may successfully reverse resource exhaustion if agents are willing to invest a sufficient amout of resources in this endevour. In addition to a Baseline condition in which restoration technologies are never available, we investigate four treatments, manipulating the cost (High versus Low) and uncertainty of restoration availability (Certain versus Uncertain) with a factorial design.

Our results show that heavy reliance on restoration, which crowds out sustainable harvesting strategies, occurs only when restoration technologies are cheap and available with certainty. In all other cases, players tend to conform with the behavioral pattern observed in the Baseline, where most groups succeed in coordinating on a virtuous, feasible harvesting equilibrium. In addition, the presence of restoration technologies neither allows groups to conserve the resource for longer nor to accrue higher earnings, net of short-term effects. Instead, it contributes to exacerbating earnings inequality within groups. This evidence underscores the validity of concerns about the risk that NETs crowd out short-term mitigation efforts, particularly when these fail-safe mechanisms are (possibly mistakenly) perceived as low-cost and easily accessible.[2] Notably, our experimental results reveal that this undesirable effect disappears when agents recognize that reversing their previous harmful actions is either costly or uncertain.

Our paper contributes primarily to the experimental literature examining mechanisms that foster cooperation in social dilemmas, particularly in settings that mimic the key features of the climate crisis, such as dynamic public goods games and dynamic common-pool resource games (e.g., Fischer et al. 2004; Hauser et al. 2014; Battaglini et al. 2016; Gächter et al. 2017; Tasneem et al. 2017; Calzolari et al. 2018; Cason and Zubrickas 2019; Vespa 2020; Lohse and Waichman 2020; Nockur et al. 2020).[3] These studies explore how the evolution of durable public goods or common resources is influenced by contextual and institutional factors, such as group size, the persistence of actions on future outcomes, refund mechanisms for contributions, the action space, resource stock levels, and whether decisions are made through decentralized mechanisms or centralized processes like voting, bargaining, or peer

[2]Evidence of stark promotion efforts in favor of carbon capture and storage (CSS) technologies by fossil fuel and other high-pollution industries is widespread (`https://www.theguardian.com/environment/2023/dec/08/at-least-475-carbon-capture-lobbyists-attending-cop28`) Both online and offline — during official events such as the COP28 — interested stakeholders advertise such technologies, over-promising the capacity and effectiveness of their CSS projects, and pushing for their adoption as an opportunity to license themselves to keep their business and production plans unchanged, refraining from taking concrete actions to reduce their emissions

[3]Less directly related are experiments using static public good or common-pool resource games to study environmental sustainability, which focus on short-term incentives and outcomes (e.g., Ostrom 2008; Gächter et al. 2022; Manara et al. 2025).

punishment.

The key innovation of our design is the introduction of *reversible actions*: we extend the stage game of a dynamic common-pool resource game by incorporating a *restoration stage*, where players can make a costly investment to undo previous (potentially excessive) harmful actions. The closest contribution in this regard is Battaglini et al. (2016), who study the accumulation of a durable public good through voluntary contributions. Some of their treatments allow for *negative contributions*, enabling players to reverse earlier virtuous actions. In contrast, our framework focuses on reversing *selfish and hazardous* behavior rather than undoing cooperative actions. Moreover, while Battaglini et al. (2016) compare the effects of reversible and irreversible actions, they do not vary key aspects of the reversibility environment—such as the cost of reversing previous decisions or the uncertainty surrounding its availability—elements we manipulate explicitly in our design.

More broadly, we contribute to the growing literature that uses experimental and survey methods to examine individuals' attitudes and behaviors toward climate change and mitigation policies (e.g., Dechezleprêtre et al. 2022; Tannenbaum et al. 2022; Fabre et al. 2023; Andre et al. 2024). While these studies provide valuable insights into the drivers of (still insufficient) public support for climate mitigation, they usually rely on surveys assessing respondents' attitudes toward specific policies and focus on interventions like information provision, without accounting for emissions *removal* options. Our work complements this literature by introducing emissions removal options in a controlled experimental setting, allowing us to exogenously manipulate key features of the decision-making environment and assess their impact on mitigation efforts.

Within this strand, the closest related studies are experiments that analyze individuals' willingness to engage in voluntary carbon offsetting, focusing on the causal effects of offsets' costs and effectiveness (Rodemeier 2022) or providing information on carbon footprint reduction strategies, the reinvestment of carbon tax revenues, and the uncertainty of emissions impacts (Bernard et al. 2023; Woerner et al. 2024; Pace et al. 2025). However, unlike these studies, which center on individual decision-making, our paper models mitigation as a *cooperation problem.* We analyze group dynamics, free-riding behavior, and the trade-off between mitigation and emissions removal—an aspect absent in existing experimental designs.

Finally, the effects of Negative Emission Technologies (NETs) on mitigation deterrence have been extensively studied using Integrated Assessment Models (IAMs). These computational tools synthesize insights from climate science, engineering, and economics to generate policy-relevant projections on global environmental change and sustainable development (e.g., Emmerling et al. 2019; Bosetti 2021; Giannousakis et al. 2021; Grant et al. 2021). While this literature highlights significant risks of mitigation deterrence, particularly when uncertainties about NET scalability are overlooked, IAMs typically assume optimal decision-making from a *social planner's perspective*. As a result, they neglect the *voluntary provision* and *cooperation dynamics* that are central to real-world outcomes—elements we explicitly address in our theoretical framework and experimental analysis.

2 The Restorable Common Pool Resource Game

Building on existing work, we model the climate mitigation problem as an infinite-horizon common-pool resource game. Since our research question concerns the role of a technology that allows restoration of the resource after its exhaustion, we augment the classic paradigm and develop novel game: the *restorable common-pool resource game*.

We consider a community of $n \geq 2$ homogenous individuals who interact for an infinite number of periods and discount future payoffs with a factor $\delta \in [0, 1]$. Each period $t = \{1, 2, \ldots, \infty\}$ features an *Extraction* and a *Restoration Phase*.[4]

In the **Extraction Phase**:

- The common pool resource counts $K > 0$ units.
- Each player i receives an endowment $w > 0$.
- Each player i makes simultaneously an individual extraction choice $e_{it} \in \left[0, \frac{K}{n}\right]$.
- If $\sum e_{it} \leq T_E$, the resource is conserved, and the game continues to another period.
- If, instead, $\sum e_{it} > T_E$, the game continues to the Restoration phase with probability $\rho \in [0, 1]$; the resource is exhausted and the game ends with probability $(1 - \rho)$.

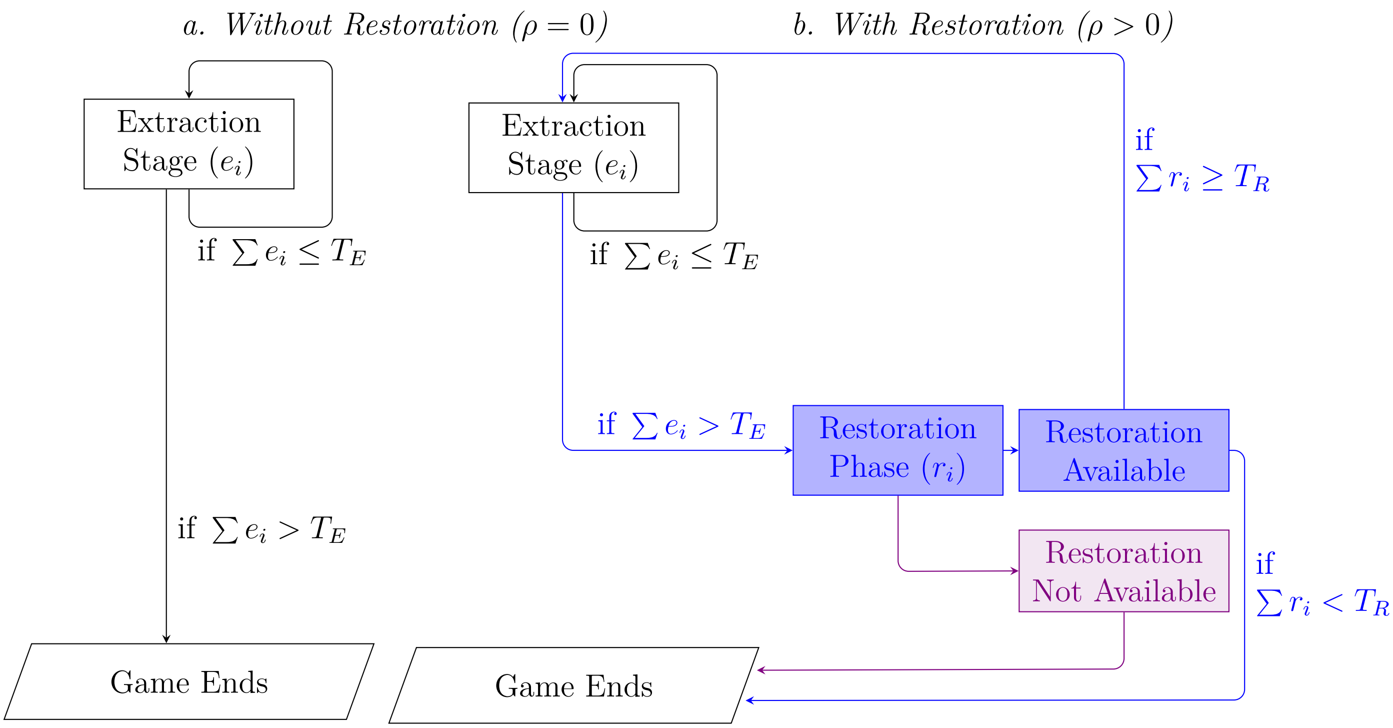
In the **Restoration Phase** (if reached):

- Each player makes simultaneously an individual restoration choice $r_{it} \in [0, w]$
- If $\sum r_{it} \geq T_R > 0$, the resource is restored, and the game continues to another period
- If, instead, $\sum r_{it} < T_R$, the resource is exhausted and the game ends

Player i's utility in period t is given by $u_{it} = w + e_{it} - r_{it}$, where w is the initial endowment, e_{it} is the individual benefit from extraction, r_{it} is the individual cost from restoration. Assuming $r_{it} \leq w$ guarantees $u_{it} \geq 0$, which is useful for the experimental implementation. We make two additional assumptions.

[4]Figure 1 summarizes the timing of a single period in the infinite-horizon game.

Figure 1: Dynamics of the Restorable Common Pool Resource Game



Panel a: In the absence of restoration technologies, the game only counts one stage — the Extraction Stage — in which each group member makes an extraction choice (e_i); if total extractions do not exceed the threshold ($\sum e_i \leq T_E$) the game continues to another period, reaching a new Extraction Stage; otherwise, the game ends immediately. *Panel b:* In the presence of restoration technologies, the game counts two stages: the Extraction Stage and the Restoration Stage. In the latter, each group member makes a restoration choice (r_i) that is relevant only if total extractions exceed the threshold and restoration is available; if Restoration is available and aggregate restoration is high enough ($\sum r_i \geq T_R$), the game continues to another period, reaching a new Extraction Stage; if instead, Restoration is available, but aggregate restoration is not high enough ($\sum r_i < T_R$), the game ends; if Restoration is not available and total extractions exceeded the threshold, the game ends as in the case without restoration.

Assumption 1 (No Unilateral Conservation) *We assume that* $\left(\frac{n-1}{n}\right) K > T_E > 0$*, that is, a single group member cannot unilaterally conserve the resource in the Extraction Phase if everybody else is extracting maximally.*

Assumption 2 (No Unilateral Restoration) *We assume that* $K > T_R > \frac{W}{n}$*, that is, a single group member cannot unilaterally restore the resource in the Restoration Phase if everybody else makes no restoration effort.*

2.1 Equilibrium Analysis

We focus on symmetric and stationary subgame perfect Nash equilibria (SPNEs) of the game. We note that there can only be (at most) four symmetric and stationary SNPEs:[5]

1. (*Extract, Don't Restore*) where, in each period, $e_i^\star = \frac{K}{n}$ and $r_i^\star = 0$
2. (*Conserve, Don't Restore*) where, in each period, $e_i^\star = \frac{T_E}{n}$ and $r_i^\star = 0$
3. (*Extract, Restore*) where, in each period, $e_i^\star = \frac{K}{n}$ and $r_i^\star = \frac{T_R}{n}$
4. (*Conserve, Restore*) where, in each period, $e_i^\star = \frac{T_E}{n}$ and $r_i^\star = \frac{T_R}{n}$

In Appendix A, we characterize conditions on the game's parameters for each of these four potential equilibria to exist. The (Extract, Don't Restore) equilibrium exists for any degree of patience because, according to Assumptions 1 and 2, if a player believes others are extracting as much as they can and investing as little as they can in restoration, there is nothing he can unilaterally do to conserve or restore the resource and behaving selfishly in both stages is the best response. When, instead, players believe others are cooperating, an equilibrium with (perpetual or temporary) resource preservation is feasible as long as players are sufficiently patient to give up the immediate gratification of greater resource exploitation and smaller restoration investment for the delayed benefit of longer resource life. As the sustainable level of extraction (T_E) grows, the players' degree of patience needed to support the equilibrium (Conserve, Don't Restore) decreases. On the other hand, as the

[5]Payoffs in a period are strictly increasing in e_{it} and strictly decreasing in r_{it}. Moreover, transition probabilities across periods and phases within a period are insensitive to marginal changes in e_{it} unless $\sum e_{it} = T_E$, and insensitive to marginal changes in r_{it} unless $\sum r_{it} = T_R$. It follows that, in any period of any symmetric and stationary equilibrium, players must choose either $e_{it} = \frac{K}{n}$ (i.e., maximal extraction) or $e_{it} = \frac{T_E}{n}$ (i.e., the largest symmetric extraction which ensures conservation). Similarly, they must choose either $r_{it} = 0$ (i.e., minimal restoration) or $r_{it} = \frac{T_R}{n}$ (i.e., the minimal symmetric restoration which avoids exhaustion). No other strategy can be part of a symmetric and stationary equilibrium because, if that were the case, each player could unilaterally deviate and extract marginally more (thus increasing the payoff in the current period) without changing the transition between periods or between phases within the same period (thus, leaving the continuation value of the game unchanged).

investment required for restoration (T_R) grows, the players' degree of patience needed to support the (Extract, Restore) equilibrium increases.

We also highlight that while the outcomes on the equilibrium path and the efficiency of the (Conserve, Restore) equilibrium are the same as in the (Conserve, Don't Restore) equilibrium, the equilibrium with restoration off the equilibrium path (which only exists when restoration is available) can be harder to sustain in terms of players' degree of patience (and, indeed, this will be the case with our experimental parameters). This is due to the moral hazard or mitigation deterrence risk discussed in the Introduction.

Finally, we note that multiple equilibria coexist for a wide range of parameters. While equilibrium selection is one of our main research questions (and, thus, experimental parameters were purposefully chosen to ensure equilibrium multiplicity in all treatments), one criterion that can be used to refine predictions and select one equilibrium ex-ante is the efficiency of equilibrium outcomes (in a utilitarian sense). First, when they exist, both the (Conserve, Don't Restore) equilibrium and the (Extract, Restore) equilibrium Pareto dominate the (Extract, Don't Restore) equilibrium. Second, when restoration is available with certainty, the (Extract, Restore) equilibrium is more efficient than the (Conserve, Don't Restore) equilibrium if and only if $K - T_R > T_E$, that is, depending on what equilibrium leads to a greater aggregate per period consumption.

3 Experimental Design

We conducted the experimental sessions in June 2023 at the Bocconi Experimental Laboratory for the Social Sciences with students from Bocconi University recruited from a database of volunteers.[6]

Treatments. We used a between-subject design to implement five treatments, manipulating restoration technologies' availability and cost, as detailed in Table 1. In all treatments, we use a neutral framing, without mentioning the climate or the environment; groups are composed of $n = 5$ members; at the beginning of each period, the common resource counts $K = 100$ units; in each period, each group member receives an endowment of $w_{it} = 20$ units and chooses simultaneously and independently how much to extract from the resource, between a minimum of 0 and a maximum of $\frac{K}{n} = 20$ units; if the total extraction in a period exceeds $T_E = 50$, the resource is depleted (irreversibly so when restoration technology

[6]The study was approved by the Bocconi University Ethics Committee on February 20, 2023 (FA000565) and pre-registered on AsPredicted on May 22, 2023 (#133060). The pre-registration is available at https://aspredicted.org/ZS8_3Q5. The experimental instructions are available in Appendix J.

Table 1: Experimental Design

Treatment	ρ	T_E	T_R	Sessions	Subjects	Groups
T1 - No Restoration (Baseline)	0	50	–	6	120	312
T2 - Uncertain / Low	0.5	50	25	6	120	216
T3 - Certain / Low	1	50	25	6	120	184
T4 - Uncertain / High	0.5	50	75	6	120	208
T5 - Certain / High	1	50	75	6	120	196

Notes. ρ denotes the probability restoration is available; T_E and T_R denote threshold values for group total extraction and restoration choices, respectively. The total number of groups varies across treatments due to the different number of supergames played per session. See Table 11 in Appendix G for descriptive statistics about the total number of supergames played per treatment.

is unavailable); if, instead, the total extraction in a period is less than T_E, the resource regenerates and the game continues for another period; the discount factor is $\delta = 0.8$ and is implemented through a block random termination rule protocol (Fréchette and Yuksel 2017).[7]

The ***Baseline*** treatment is a standard infinite-horizon common-pool resource game. No restoration technologies are available; thus, if the total extraction in a period exceeds $T_E = 50$, the resource is irreversibly depleted, and the game ends. We introduce restoration technologies in four additional treatments where, using a factorial design, we manipulate (a) whether the ability to restore is ***Certain*** ($\rho = 1$) or ***Uncertain*** ($\rho = 0.5$); and (b) whether the cost of restoration, that is, the minimum total effort needed for restoration to undo depletion successfully, is ***High*** ($T_R = 75$) or ***Low*** ($T_R = 25$). Table 1 summarizes.

Choices and Beliefs. We elicit restoration choices using the strategy method, in which a respondent makes conditional decisions for each possible information set (Brandts and Charness 2011; Fischbacher et al. 2012). In our environment, this means that participants make restoration choices after they make their extraction choices, but before they learn whether the restoration stage is eventually reached, that is, before they know whether total group extraction was excessive — and restoration technologies available in treatments with uncertain restoration. While restoration choices are elicited in every period, they are payoff-relevant only when the restoration stage is reached. We opt for this method (rather than the direct response method) to obtain observations at both stages of our game without selection issues. At the end of each period, subjects learn the status of the resource and

[7]Participants play in blocks of 5 rounds, as long as the resource is conserved (as determined by total extraction in a period). At the end of each block, participants learn the realizations of the random number, determining whether the game continued or not at the end of each period in the block, how many rounds in the block mattered for their earnings, and if the game continued to another block.

receive comprehensive feedback on total group extraction and restoration (if available) levels reached, including a breakdown detailing the choices made by each group member. The experiment is divided into two parts: Part 1 includes the first six supergames; Part 2 consists of the other supergames. In Part 2, we also elicit participants' beliefs about the sum of the other group members' extraction and restoration choices. We do this at the end of each period before participants receive the end-of-period feedback.

Supergames. All sessions count 20 participants. At the beginning of each *supergame* (a repetition of the infinite-horizon game), we form four groups of five members. We use a partner matching protocol within supergames and a stranger matching protocol across supergames. A supergame ends when either (i) the random termination rule decides so or (ii) the resource is depleted and not restored in the round. Participants play all supergames started within 60 minutes from the beginning of the first supergame.[8] To reduce concerns related to the chance that the realized length of early supergames affects participants' behavior in later supergames, possibly interacting with or confounding the effect of our treatments, we control for supergames' realized length across treatments (Mengel et al. 2022).[9]

Earnings. Participants are paid for their cumulative payoff in one randomly selected supergame from Part 1 and one randomly selected supergame from Part 2. In addition, we select one round of a different supergame played in Part 2 and pay a fixed prize to participants whose reported belief about the sum of the other group members' extraction or restoration choices is accurate.[10] Each session lasted approximately 90 minutes, and participants earned, on average, €27.6, including a €7.5 show-up fee.

Sample Size. We recruited 600 participants and split them equally across the five treatments, resulting in 120 participants per treatment. This sample size is based on the behavior

[8]After reading the instructions and before the first supergame, subjects answer three comprehension questions and have up to two attempts to answer them correctly. If they fail, subjects are not excluded from the session but can continue only after a debriefing session with the experimenter. This ensures all subjects understand the instructions well before playing the first supergame. Table 12 in Appendix G shows the performance in the comprehension quiz.

[9]In particular, we use the following procedure: i) we organize experimental sessions in batches of 5 sessions each, in which one session per each treatment condition is included; ii) within each batch, we let the software randomly determine the length of all (potential) super-games to be played for the first session (in which participants are assigned to the Baseline treatment); the same realizations are used to determine the length of all (potential) super-games to be played in all other sessions belonging to the same batch.

[10]Both beliefs we elicit can range between 0 and 80. As in Aoyagi et al. (2024), we randomly draw two numbers from $[0; 80]$, and the belief is considered to be accurate if the distance between the actual value and participants' stated belief is smaller than the distance between the actual value and any of the two randomly extracted numbers.

we observed in two pilot sessions we conducted in March 2023 with 20 participants in the Baseline treatment and 20 participants in the Certain Restoration/Low Cost treatment.[11]

Theoretical Predictions. Given our experimental parameters, the (Extract, Don't Restore) equilibrium exists in all treatments, regardless of δ; the (Conserve, Don't Restore) equilibrium exists in all treatments as long as $\delta \geq 1/4$; the (Extract, Restore); and the conditions for the existence of the (Extract, Restore) and (Conserve, Restore) equilibria in the four treatments where restoration is available ($\rho > 0$) are summarized in Table 2. Since we use $\delta = 4/5$, our careful choice of experimental parameters leads to multiple equlibria: in all treatments, both equilibria with immediate depletion and equilibria with longer resource life exist. At the same time, the introduction of the restoration technology expands the set of equilibria compared to the Baseline treatment, since conservation can be achieved either through limited extraction and no need for restoration or through exploitation followed by restorative efforts. While the experiment is meant to provide evidence of participants' coordination on a particular equilibrium (and on how this might change as a function of the treatment), we can make sharper theoretical predictions by focusing on the most efficient SPNE, an equilibrium refinement commonly used in the literature on dynamic games (see, for example, Dixit et al. 2000). Given our experimental parameters, the SPNEs that deliver the largest sum of discounted utilities at the beginning of the game are (Conserve, Restore) and (Conserve, Don't Restore) in all but one treatment. The exception is the treatment with Certain Restoration ($\rho = 1$) and Low Cost ($T_R = 25$), where the efficient equilibrium prescribes maximal extraction followed by restoration.

4 Discussion of Experimental Design

Our experiment investigates a complex common resource management problem with intertemporal and uncertain dynamics. To recreate this environment in a controlled laboratory setting, we distilled the key aspects of the real-world problem into a simplified, stylized

[11]The goal of these sessions was to check participants' comprehension of the instructions and to make distributional assumptions for power calculations. Using standard values for significance level ($\alpha = 0.05$) and statistical power ($\beta = 0.80$), the sample size we settled on would allow us to detect a minimum treatment effect size of 0.3 standard deviations on average Round 1 individual extraction choices in cross-sectional analyses. This corresponds to a variation of approximately one unit in individual extraction behavior, the smallest yet economically relevant variation in the outcome of interest. This sample size would also allow us to reach a minimum detectable effect size of approximately the same size in the presence of mild intra-correlation within clusters (experimental sessions). After these pilot sessions, we slightly modified the experimental protocol and software interface (to increase understanding of the block random termination rule and to measure beliefs about the behavior of others in a subset of infinite-horizon games). We do not use data from these pilot sessions in the analyses.

Table 2: Conditions for Existence of Equilibria with Restoration in Treatments with $\rho > 0$

	High Cost ($T_R = 75$)	**Low Cost** ($T_R = 25$)
Certain Restoration ($\rho = 1$)	(Extract, Restore): $\delta \geq 3/8$ (Conserve, Restore): $\delta \geq 1/3$	(Extract, Restore): $\delta \geq 1/8$ (Conserve, Restore): NO
Uncertain Restoration ($\rho = 0.5$)	(Extract, Restore): $\delta \geq 3/8$ (Conserve, Restore): $\delta \geq 1/3$	(Extract, Restore): $\delta \geq 1/8$ (Conserve, Restore): $\delta \geq 1/3$

game. This section outlines the critical design choices underlying our approach.

Experimental Manipulations. Our treatment scenarios allow us to investigate how two critical uncertainties—NETs' implementation costs and their availability for large-scale deployment—affect the perceived substitutability between mitigation and restoration. Manipulating these features is central to addressing our research question. First, we recognize that NETs are unlikely to fully reverse the effects of past emissions, either due to their limited potential or the irreversibility of damages caused by past emissions (Schleussner et al. 2024). To capture this aspect, we model NETs as probabilistically available in a subset of our treatments. Additionally, we mirror the complexities arising from the uncertainty surrounding the readiness and implementation costs of various technologies and the prospect that large-scale deployment will require a combination of different solutions by varying NETs' implementation costs across treatment conditions.

Dynamic Linkage between Periods. One key difference between our framework and the real-world problem lies in the absence of stock dependency.[12] In our game, the dynamic linkage between periods is given by whether the resource is exhausted or still available, as determined by past group members' choices. However, if the resource remains available, each new period is identical to previous ones, and past resource use does not influence the cost, likelihood, or effectiveness of NET implementation. This simplification trades realism for simplicity and it allows us to generate clear, testable predictions, which path dependencies would complicate. We note that introducing stock dependency would be analogous to increasing the cost of restoration—a dimension we examine through treatment manipulations. For instance, linking restoration costs to resource extraction levels or allowing past resource exploitation to reduce agents' restoration capacity across periods would make restoration im-

[12] This simplification departs from real-world dynamics in the case of carbon dioxide (CO2) emissions and removal. However, it may better represent methane (CH4), for which NETs are still in development. Despite its higher energy absorption and rapidly increasing atmospheric concentration, methane has a much shorter atmospheric lifetime than CO2 International Energy Agency, 2024, making the lack of stock and state dependency less critical in the context of methane removal.

plementation more challenging. Thus, while acknowledging the limitation of our design, we interpret our results as representing an optimistic scenario, where restoration is unbounded by stock effects and successful restoration negates the impact of overexploitation.

Sequential Decision Stages. A key feature of our design is the inclusion of two distinct and sequential decision stages—one for extraction and another for restoration—where choices are made and aggregated separately, rather than combining both decisions into a single stage. This structure mirrors the separation of negotiation processes for emissions reductions and removal, as advocated by both natural and social scientists (McLaren et al., 2019; Brad and Schneider, 2023; Andreoni et al., 2024). It also captures a crucial, often overlooked aspect of the real-world problem: large-scale implementation of negative emissions will fundamentally increase the level of international cooperation required to combat climate change. Currently, cooperation efforts focus primarily on emissions reduction. However, the introduction of negative emissions technologies (NETs) adds another layer of complexity, necessitating additional coordination to ensure their effective implementation and use. While early implementation may be driven by scattered, uncoordinated actions of a few technological leaders, large-scale deployment will eventually require collective, multi-actor cooperation due to the significant costs and complex governance involved. This consideration also underpins our design assumption that unilateral conservation and restoration efforts alone cannot guarantee resource sustainability, emphasizing the need for collective action in both dimensions.

Deterministic Thresholds. In our setting, resource conservation depends on whether collective actions meet known and deterministic thresholds: failure to meet these thresholds results in sudden and extreme changes in resource status, regardless of the magnitude of the deviation. This approach simplifies the decision environment and avoids the interaction of multiple uncertainties in treatments where NETs may not always be available. While this simplification captures a critical aspect of climate change damages, we acknoledge that it does not reflect the gradual transformations that can occur when thresholds are exceeded in reality.[13] At the same time, we note that recent experimental evidence underscores the relevance of threshold thinking in climate change, reflecting how many people conceptualize the problem despite its scientific imprecision (Semken 2024).

Complete Reversibility. Another simplification in our design is the assumption of complete reversibility of adverse outcomes, which diverges from real-world scenarios where ir-

[13]Barrett and Dannenberg, 2012 show that introducing uncertainty in thresholds within a static public good game significantly reduces contribution levels compared to deterministic thresholds.

reversible tipping points pose significant challenges. Introducing incomplete reversibility would likely reinforce our findings, as it would make restoration even more challenging and emphasize the importance of proactive mitigation efforts.

Long-Lived Players. We model the problem as an infinitely repeated game played by the same group of agents, representing the current generation of policymakers who regularly negotiate and discuss technology implementation, similar to the annual Conference of the Parties under the United Nations Framework Convention on Climate Change (UNFCCC). In reality, the mitigation deterrence challenge is heightened by the disproportionate impact of suboptimal mitigation decisions on future generations. As such, our results on mitigation cooperation can be interpreted as an upper bound, reflecting a best-case scenario. In a more realistic setup, where the game is played sequentially by different, not fully altruistic generations, cooperation outcomes would likely be less favorable.[14]

Patient Players. In our experiments, we use a high discount factor ($\delta = 4/5$), inducing relatively patient behavior among agents. This choice serves two key purposes. First, it extends the expected duration of interactions, enabling us to study resource longevity and long-run outcomes.[15] Second, it aligns with our focus on strategic tensions that may arise from long-term NETs implementation once countries approach net-zero targets through mitigation efforts. A high discount factor encourages substantial cooperation, fostering conservative resource use even without negative emissions. Indeed, our primary objective is not to assess whether NETs can compensate for insufficient mitigation efforts but to explore their potential side effects in scenarios where full decarbonization could already be achieved through mitigation alone. Specifically, we investigate how the introduction and characteristics of NETs influence strategic behavior, potentially undermining mitigation efforts or reducing welfare in otherwise cooperative contexts. Furthermore, this parameterization ensures comparability with prior experimental studies using dynamic common pool resource games to examine climate cooperation (Hauser et al., 2014).

[14]Our Baseline treatment is identical to one of the treatments in **?**, and this allows us to gauge the effect of intra-generational versus inter-generational cooperation. In our Baseline treatment, where the same group of players interacts repeatedly, around 80% of our experimental communities conserve the common resource for more than one period (see Figure 3). In the 'Unregulated' treatment in Hauser et al., 2014, where a group is composed of new players (or 'generations') at every period, around 20% of experimental communitiesconserve the resource after Round 1 (see Figure 2a in their paper).

[15]Under the random termination rule, the expected number of periods in a supergame is $1/(1-\delta)$, resulting in an average duration of 5 periods when $\delta = 4/5$.

5 Experimental Results

Results reported in this section refer to the behavior of "experienced" participants, starting from the 4^{th} supergame onwards, as pre-registered.[16] When presenting results about beliefs, we use data from the 7^{th} supergame, in which beliefs are first elicited. When discussing results about choices and beliefs, we focus on the first round of a supergame. This is standard practice for the analysis of experimental data from infinitely repeated games and simplifies the analysis by i) minimizing the impact of history on behavior, as history may differ across subjects/groups starting from the second round, and ii) increasing comparability, as the length of each supergame may differ across subjects/groups due to the combined effect of their choices and the random termination rule. For the same reasons, we focus on the first block (rounds 1-5) of a supergame when discussing resource life length and cumulative earnings results.[17]

5.1 Extraction and Restoration Choices

In the Baseline condition, in the absence of restoration, participants tend to extract a sustainable amount, allowing the resource to survive, on average, for four periods.[18] As a result, participants' payoffs are close to the efficient levels that can be achieved through sustained cooperation, and payoff dispersion is low. Overall, results show that the availability of restoration technologies neither allows participants to conserve the common resource longer nor to accrue higher payoffs than in the Baseline.

In the presence of restoration, it is only when the restoration technology is certain and cheap (T3) that players converge — and consistently stick — to the profitable actions' pattern in which the resource is first exhausted due to high extraction levels and then replenished through restoration technologies (see Figure 2 reporting evidence on Round 1 choices).[19] Interestingly, while participants invest the amount needed to make restoration successful from the beginning, they only learn over time to extract the resource to the full extent before replenishing it, fully exploiting the strategic substitutability.

When the restoration technology is cheap but uncertain (T2), most players tend to play

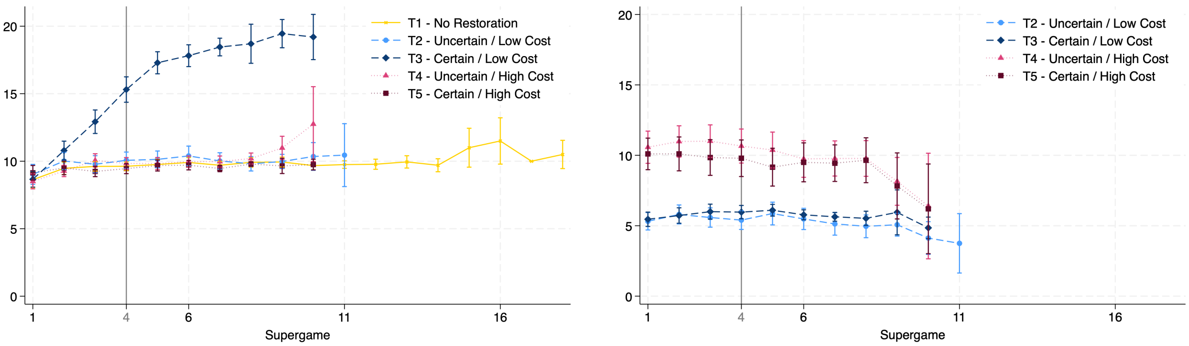
[16]In Appendix C, we show that the results presented in this Section are qualitatively unchanged when we expand the analyses to the whole sample. We compare subjects' behavior in early (1 to 3) vs. late (4-onwards) supergames in Appendix E.

[17]In Appendix D, we show that results are qualitatively unchanged if we relax these constraints and include data from all rounds and all supergames.

[18]Note that with a continuation probability of $\delta = 0.8$ the expected duration of the game is five periods.

[19]See Figure 9 in Appendix H for descriptive statistics and results of non-parametric tests on overall Extraction and Restoration choices by experienced subjects in Round 1 (pooling observations from all supergames), and Table 13 in Appendix G for ATEs on individual Extraction and Restoration levels.

Figure 2: Mean Individual Extraction and Restoration Choices, Round 1



Notes. Whiskers denote 95% confidence intervals. *Left panel*: Extraction; *Right panel*: Restoration.

conservatively on extractions, consuming virtually the same amount of units from the common pool as in the Baseline. However, similarly to what we observe in the companion treatment with cheap restoration (available with certainty, T3), participants also choose to invest, on average, the amount needed to make restoration technologies effective despite the uncertainty about their actual availability.

When restoration technologies are expensive, irrespective of whether their availability is certain (T5) or uncertain (T4), players tend to play conservatively on extraction choices, just as in the Baseline, in which no restoration option is available. At the same time, although their conservative extraction conduct rarely makes restorative interventions needed, participants also tend to engage, on average, in positive restoration efforts.

RESULT 1: *The only condition in which restoration technologies are consistently employed, in combination with exploitative extraction actions, is when they are certain and cheap.*

5.1.1 Group and Individual Heterogeneity

To investigate heterogeneity at the group level, we classify each group with the equilibrium profile that most closely describes their observed aggregate group action (i.e., total extraction and total restoration) in Round 1. In the Baseline condition, individual extraction choices exhibit low variability when no restoration option is available. Looking at aggregate group behavior, we observe that in the majority of cases, action patterns compatible with what the conservative and most efficient equilibrium *"Conserve, Don't Restore"* would prescribe emerge, and only a minority of all groups exceeds the extraction threshold, exhausting the resource in the first round of play (see Figure 3).[20]

[20]See Figure 10 in Appendix H for further descriptive evidence on the dispersion in Round 1 extraction and restoration choices.

When restoration is certain and cheap (T3), both extraction levels and variability in individual extraction choices are higher. At the same time, relatively little heterogeneity is observed in restoration choices, whose value fluctuates around the (symmetrical) due level. As a result, in this treatment, most groups coordinate on extraction and restoration actions compatible with the most profitable (and efficient) equilibrium *"Extract, Restore"*.

When restoration is cheap but uncertain (T2), the average number of units extracted from the resource is not statistically different from the baseline. In contrast, the average restoration effort mirrors the level reached in the companion treatment with cheap but certain restoration technologies (T3). However, due to a composition effect driven by the higher variability in individual extraction choices, aggregate group extraction levels exceed the threshold more often than in the Baseline.[21] Similarly, while the average restoration effort is high enough to reach the threshold needed at the group level in the majority of cases, the higher variability in individual restoration choices makes group restoration efforts sufficient less often than in T3.[22] Looking at aggregate group behavior, we observe that the conservative equilibrium *"Conserve, Restore"* — in which a limited amount of resource units is extracted and, simultaneously, efforts needed to make restoration effective are met — emerges as the most frequent. The other two equilibria *"Conserve, Don't Restore"* and *"Extract, Restore"* follow with almost equal frequency (see Figure 3), and similarly to what we observe in the Baseline and T3, only a minority of groups coordinate on the defective and inefficient equilibrium *"Extract, Don't Restore"*.

When restoration technologies are expensive, irrespective of whether their availability is certain (T5) or uncertain (T4), we observe a slightly higher variability in extraction choices compared to the Baseline, similar to when cheap but uncertain restoration is available. At the same time, starkly higher variation in individuals' restoration investment choices emerges: while some participants decide not to invest at all, others choose instead to invest the due amount needed to make costly restoration actions successful. In most cases, such uncoordinated restoration efforts lead to insufficient investment levels, causing groups to fail to reach the restoration threshold. As a result, the majority of groups coordinate on the *"Conserve, Don't Restore"* equilibrium, as in the Baseline, and only a minor share of all groups coordinate (and successfully persist) on extraction and restoration paths compatible with equilibria in which the resource survival relies on coordinated restoration efforts.

To further investigate heterogeneity in individual choices within and across treatments,

[21] See Table 13 in Appendix G for ATEs on the probability excessive extraction and sufficient restoration effort is observed at the group level.

[22] In addition, as shown in Table 14 in Appendix G, reporting summary statistics on the resource restoration dynamics, the restoration technology proves successful in counteracting resource exhaustion only around 1/3 of the time due to the randomness in the availability of the restoration technology.

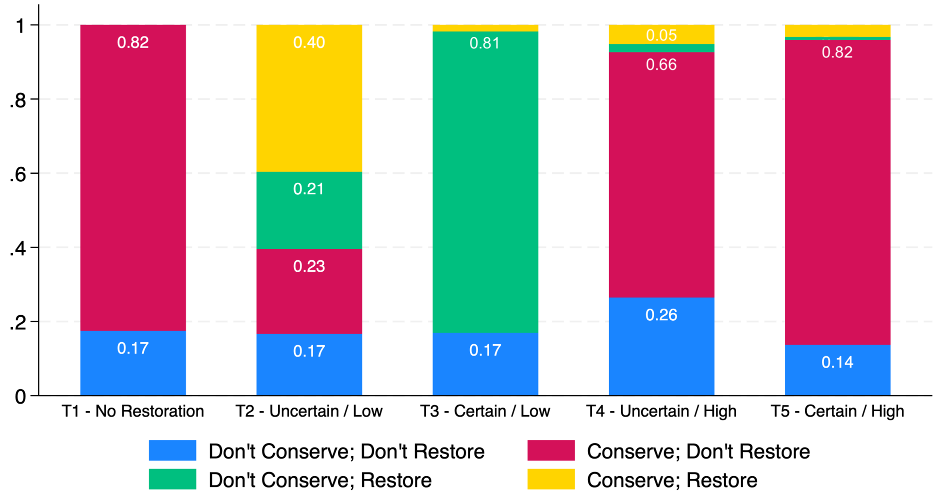
we analyze participants' behavior in treatments where restoration technologies are available through a *k-means clustering* analysis.[23] We analyze participants' behavior in low- vs. high-cost restoration treatments separately: each observation represents a participant who is identified with a two-dimensional vector describing her average extraction and restoration choices in Round 1 across all supergames played from the 4^{th} onwards. Results, shown in Figure 4, show that participants' behavior can be parsimoniously classified into three clusters within each cost condition. However, clusters' classification differs substantially across the two conditions: while in the low-cost scenarios, most heterogeneity across individuals arises from differences in average extraction choices, when restoration costs are high, clusters differ mainly only along the average restoration choice dimension. In low-cost restoration treatments, the majority of participants can be classified within one of the two clusters characterized by average extraction and restoration actions compatible with what the two equilibria *"Extract, Restore"* and *"Conserve, Restore"* would prescribe, which are the two modal equilibria in T2 and T3, respectively, based on aggregate group actions. Only a minority of participants are classified within a residual cluster characterized by conservative extraction choices and a generous restoration propensity, which is not predicted by any of the symmetrical and stationary equilibria analyzed yet could — in principle — identify participants with strong identity preferences for resource preservation, less sensitive to strategic substitutability. When restoration is expensive, clusters only differ in terms of average restoration propensity. As in the previous cost scenario, most of the participants can be classified within one of the two clusters compatible with what the two equilibria *"Conserve, Restore"* and *"Conserve, Don't Restore"* would prescribe, and only a minor share of participants are classified within a residual cluster characterized by relatively high but insufficient restoration efforts, which is not predicted by any of the symmetrical and stationary equilibria analyzed.

5.2 Resource Life

Thanks to the implementation of the block random termination rule, all players can — in principle — play for up to five rounds, irrespective of (and before being informed about) the random realizations of the parameter determining game continuation. Looking at players'

[23]K-means clustering is a common unsupervised learning technique used to group observations based on their similarity in a multidimensional space of observable characteristics (see MacQueen 1967, Hartigan 1975, Hastie et al. 2005, and Murphy 2012; for a recent use in experimental economics, see Fréchette et al. 2022). The process involves randomly selecting k points as cluster centers within the observable characteristic space. Each observation is then linked to its nearest center, and the center positions are iteratively adjusted to minimize within-cluster variance. This process is repeated 10 times with 10 different random cluster centers, and the algorithm selects the best result if the final clusters differ. Determining the initial number of clusters is a necessary step, and we followed the customary practice of using the elbow method.

Figure 3: Distribution of Group Types Across Treatments, Round 1



Notes. Group types are defined based on aggregate group extraction and restoration actions in Round 1 of all supergames played from the 4^{th} onwards.: groups are classified with the equilibrium profile that most closely describes their observed overall group action pattern. Percentage values reported inside the bars represent the frequency of the types within each treatment condition (labels are printed only for percentage values above 0.02). *EQ1:* if $E_t = \sum e_{it} > T_E$ and (if available) $R_t = \sum r_{it} < T_R$; *EQ2:* if $E_t = \sum e_{it} \leq T_E$ and (if available) $R_t = \sum r_{it} < T_R$; *EQ3:* if $E_t = \sum e_{it} > T_E$ and (if available) $R_t = \sum r_{it} \geq T_R$; *EQ4:* if $E_t = \sum e_{it} \leq T_E$ and (if available) $R_t = \sum r_{it} \geq T_R$.

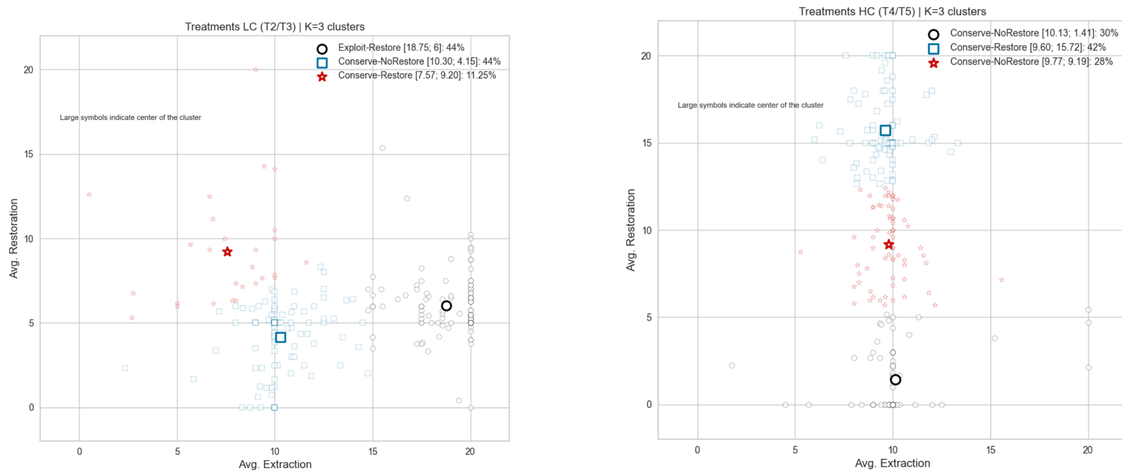
behavior in the first five rounds of each supergame — Block 1 — we observe that the resource survives for, on average, approximately four periods.[24]

The presence of restoration technologies does not improve prospects of resource life length, compared to the Baseline, not even when restoration technologies are largely employed to counteract excessively exploitative extraction behaviors, such as in T3 when restoration is certain and low cost (see Figure 5[25])

[24]Due to some minor and unexpected technical issues occurred at the end of a few sessions conducted during the first week of data collection, we exclude observations from N=6 groups in total from the analysis on Block 1 behavior: groups 1,3 from session 3 (T2); group 1 from session 4 (T3); groups 1,2,3 from session 5 (T4). During those sessions, a subset of groups experienced a glitch while taking their choices in the last supergame — at different game stages — preventing them from completing to play. The glitch never occurred while subjects were making Round 1 choices; hence, no observation is excluded from the analysis of Round 1 behavior.

[25]See Appendix G, Table 15 for full regression results. Resource life length is measured as the number of rounds each group plays out of the first block of five rounds. See Figure 11 in Appendix H for descriptive statistics and results of non-parametric tests on resource life.

Figure 4: Cluster Analysis



Notes. Participants are classified into clusters, based on their average extraction and restoration choices in Round 1 of all supergames played from the 4^{th} onwards. *Left Panel*: Low-cost restoration treatments, pooled (T2 and T3); *Right panel*: High-cost restoration treatments, pooled (T4 and T5).

RESULT 2: *On average, the resource survives for about four periods, and introducing restoration technologies does not improve its life length.*

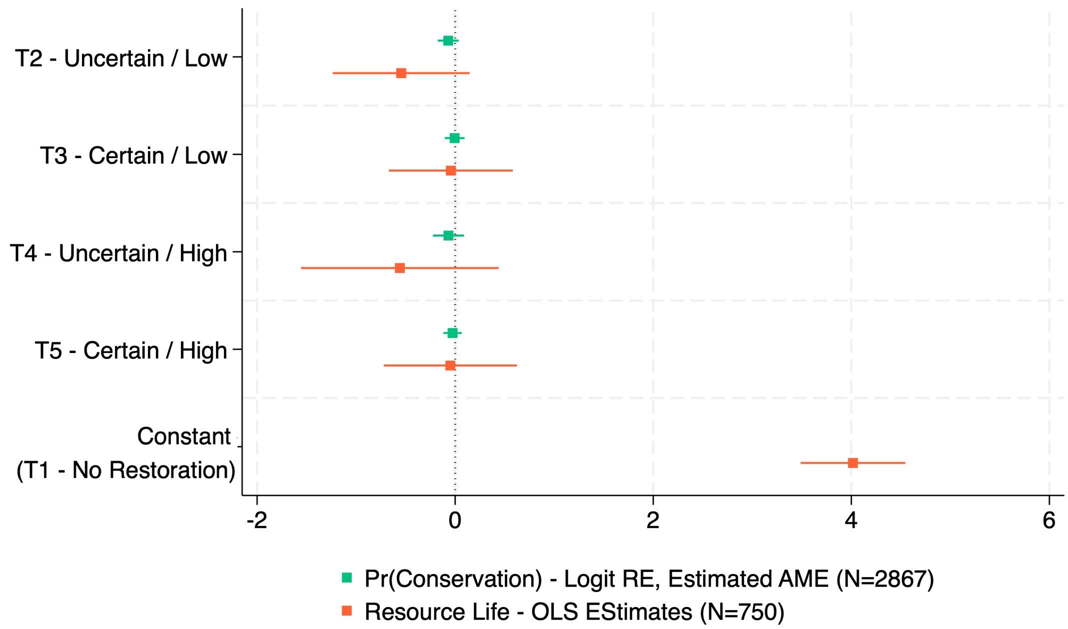
To evaluate the welfare effects of introducing restoration technologies, we primarily look at cumulative payoffs accrued over the first five rounds of a supergame — Block 1 — which are affected both by individuals' (extraction and restoration) actions in each round and by groups' ability to maximize the resource lifespan.

Overall, the presence of restoration technologies does not lead to any significant improvement in the level of cumulative payoffs, compared to the Baseline (see Figure 6[26] and Figure 8). Looking at round payoffs, the only condition in which a positive effect is observed is when restoration is cheap and certain (T3): in all other conditions, the presence of restoration technologies leads to lower round payoffs compared to the baseline in which no restoration option is available (see Figure 7).

The availability of restoration technologies also intensifies within-group dispersion in round and cumulative payoffs (see Figures 7 and 8). The strongest and most sizeable effect emerges in the presence of certain low-cost restoration technologies (T3), led by sizeable within-group dispersion in both extraction and restoration choices, with the latter being almost always payoff-relevant (due to players' exploitative actions and technological readiness).

[26]See Appendix G, Table 15 for full regression results.

Figure 5: Resource Conservation



Notes: Pr(Conservation): an observation is a group in a round of a supergame; the dependent variable is a dummy variable equal to one if the group manages to conserve the resource, either by not exceeding the extraction threshold or by successful restoration; we plot the Logit-RE estimated Average Marginal Effects, as a result, we do not report an estimate for the baseline treatment (No Restoration). Resource Life: an observation is a group in a supergame; the dependent variable is a continuous variable measuring the number of rounds the resource was conserved in; we plot estimated OLS coefficients. The baseline treatment is T1. Standard errors clustered at the session level.

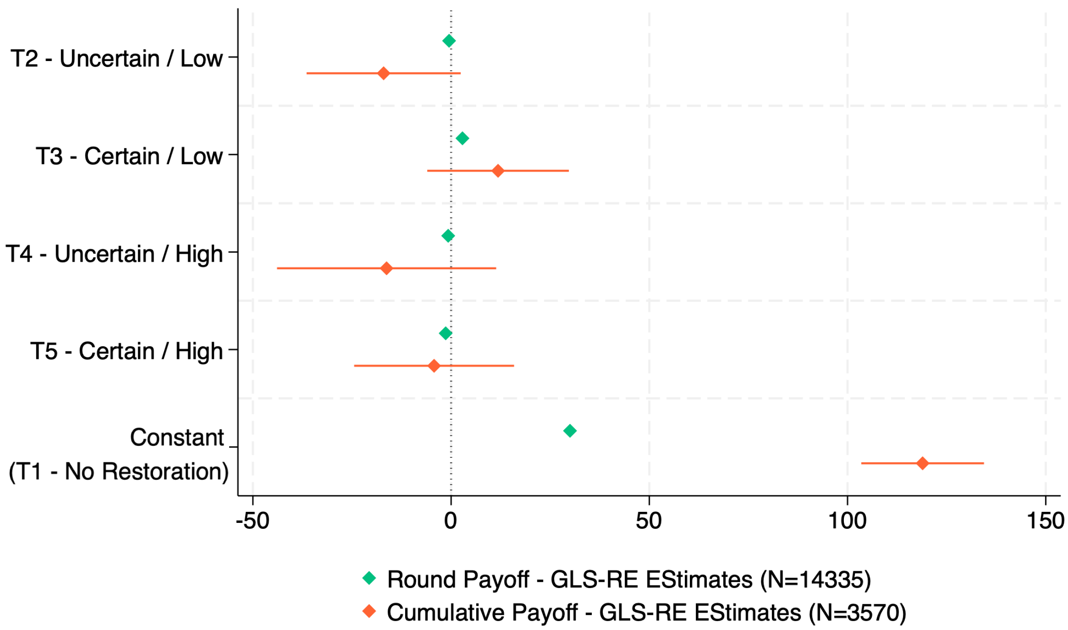
Although smaller, a significant positive effect on cumulative payoffs' dispersion also emerges when restoration technologies are low-cost but uncertain (T2) or certain and high-cost (T5). In all cases, most of the payoff dispersion observed is driven by the dispersion in extraction choices, as restoration investments — when possible — do not always lead to payoff-relevant consequences, and even when this is the case, display lower variability (see Table 3).[27, 28]

RESULT 3: *Restoration technologies do not prove to be payoff-enhancing, not even when available with certainty and at a low cost; The introduction of restoration technologies also triggers negative effects on cumulative payoffs' dispersion within groups, mostly due to a higher dispersion in players' cumulative extraction choices.*

[27] We measure dispersion looking at the standard deviation. We replicate the analysis relying on an alternative measure of dispersion - the Gini index - in Appendix I.

[28] See Figure 12 in Appendix H) for descriptive evidence on the dispersion in cumulative extraction and (payoff-relevant) restoration choices in Block 1, and Table 14 in Appendix G for summary statistics on the resource restoration dynamics.

Figure 6: Payoffs



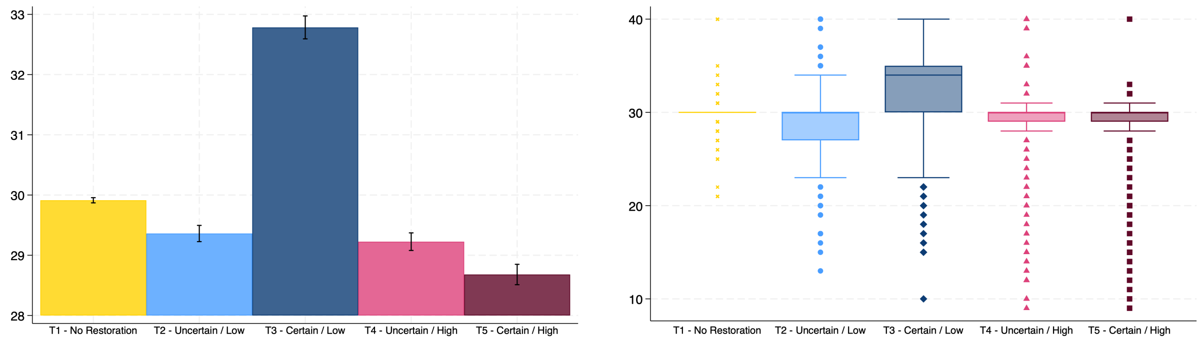
Notes: Round Payoff: an observation is a subject in a round of a supergame; the dependent variable is a continuous variable measuring individual round payoff; we plot GLS-RE estimated coefficients. Cumulative Payoff: an observation is a subject in a supergame; the dependent variable is a continuous variable measuring individual cumulative payoff accrued over Rounds 1-5; we plot GLS-RE estimated coefficients. The baseline treatment is T1. Standard errors clustered at the session level.

5.3 Beliefs

Participants tend to hold correct beliefs about their groupmates' total extraction choices in the Baseline (see Table 4), correctly approximating that their groupmates' total extraction will fluctuate around the level that would enable coordinated conservative action. Almost the same picture emerges when uncertain and expensive restoration technologies are introduced (T4). When uncertain but cheap (T2) or certain and expensive (T5) restoration technologies are available, participants expect their groupmates to extract globally slightly more of what would be the level ensuring resource conservation, although such slightly pessimistic beliefs do not match their groupmates' actual extraction patterns. In stark contrast, when restoration technologies are certain and cheap (T3), participants do correctly anticipate that their groupmates' total extraction will be well above the conservative level.

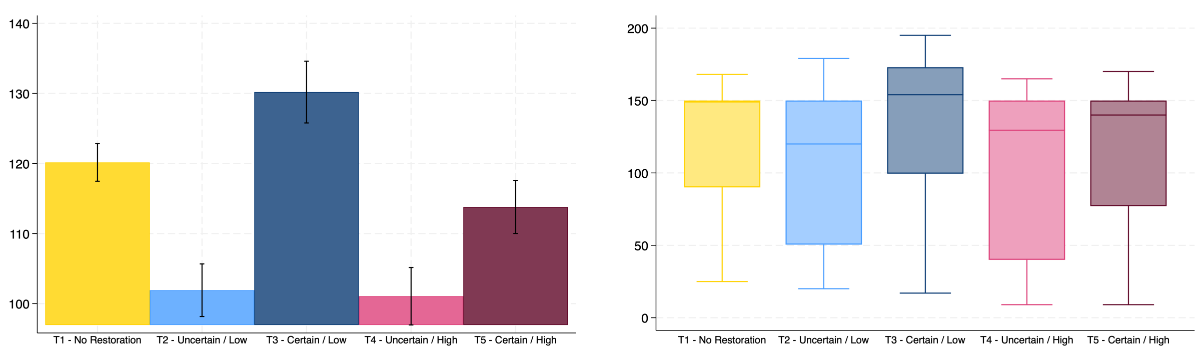
When asked to guess about their groupmates' restoration choices (see Table 4), participants correctly anticipate that their groupmates will be willing to commit to roughly sufficient investments when the cost of restoration is low (T2 and T3) but not when the cost of restoration is high (T4 and T5), when they predict that total investment will largely lag

Figure 7: Individual Round Payoffs in Block 1 (Rounds 1-5): Means & Box Plots



Notes. Left Panel - Mean values: whiskers at the top of bars denote 95% confidence intervals. Mann-Whitney-Wilcoxon test statistics on equality of medians (p-values): *T2 vs. T1* z-stat=6.341 (0.000); *T3 vs. T1* z-stat=-48.026 (0.000); *T4 vs. T1* z-stat=6.342 (0.000); *T5 vs. T1* z-stat=10.837 (0.000). Kolgomorov-Smirnov test statistics on equality of distributions (p-values): *T2 vs. T1* D=0.1544 (0.000); *T3 vs. T1* D=0.7575 (0.000); *T4 vs. T1* D=0.0636 (0.000); *T5 vs. T1* D=0.1460 (0.000). *Right Panel* - Box plots: the line inside the box denotes the median, while the upper and lower borders of the box indicate the 75th and 25th percentiles of the distribution, respectively. Whiskers' ends identify the furthest observations within one and a half interquartile range of the upper/lower ends of the box. Points marked outside of the box and whiskers correspond to outside values.

Figure 8: Cumulative Payoffs in Block 1 (Rounds 1-5): Means & Box Plots



Notes. Left Panel - Mean values: whiskers denote 95% confidence intervals. Mann-Whitney-Wilcoxon test statistics on equality of medians (p-values): *T2 vs. T1* z-stat=9.232 (0.000); *T3 vs. T1* z-stat=-9.400 (0.000); *T4 vs. T1* z-stat=9.306 (0.000); *T5 vs. T1* z-stat=5.002 (0.000). Kolgomorov-Smirnov test statistics on equality of distributions (p-values): *T2 vs. T1* D=0.2731 (0.000); *T3 vs. T1* D=0.4757 (0.000); *T4 vs. T1* D=0.2214 (0.000); *T5 vs. T1* D=0.2107 (0.000). *Right Panel* - Box plots: the line inside the box denotes the median, while the upper and lower borders of the box indicate the 75th and 25th percentiles of the distribution, respectively. Whiskers' ends identify the furthest observations within one and a half interquartile range of the upper/lower ends of the box. Points marked outside of the box and whiskers correspond to outside values.

behind the level needed, irrespective of whether the availability of the technology is certain or uncertain. Net of differences in predicted restoration effort levels, across all conditions, participants tend to hold slightly optimistic beliefs about their group mates' willingness to invest in restoration technologies.

Table 3: Analysis of Payoffs Dispersion (Block 1), Statistical Tests for ATEs

	Round Payoff *SD*	Cumulative Payoff *SD*	Cumulative Extraction *SD*	Cumulative Restoration^{PR} *SD*	Cumulative Payoff *SD*
T2 - Uncertain / Low	1.649**	4.117***	3.651**	-4.095***	
	(0.665)	(1.470)	(1.451)	(0.752)	
T3 - Certain / Low	2.212***	8.361***	6.285***		
	(0.430)	(1.747)	(1.459)		
T4 - Uncertain / High	1.307	1.798	0.475	-3.661***	
	(0.902)	(1.062)	(0.782)	(0.914)	
T5 - Certain / High	1.674***	4.873***	2.191**	-1.593*	
	(0.443)	(0.812)	(0.921)	(0.899)	
Cum. Extraction *SD*					0.884***
					(0.028)
Cum. Restoration^{PR} *SD*					0.631***
					(0.101)
Constant	1.081***	2.624***	2.624***	5.527***	0.311
	(0.298)	(0.564)	(0.564)	(0.681)	(0.277)
Observations	2867	750	750	510	510

Notes. SD: within-group standard deviation. Column 1 reports GLS-RE Estimates: an observation is a group in a round of a supergame; Columns 2-5 report OLS Estimates: an observation is a group in a supergame. In each column, the dependent variable captures dispersion, measured through within-group standard deviation, in: (1) round payoffs in Block 1; (2,5) cumulative payoffs in Block 1; (3) cumulative extraction choices in Block 1; (4) cumulative payoff-relevant restoration choices in Block 1. Restoration choices are payoff-relevant only if restoration is needed because the extraction threshold is exceeded, and available – and otherwise valued as zero. The baseline treatment in columns 1, 2 and 3 is T1 - Baseline. The baseline treatment in column 4 is T3 - Certain / Low. Standard errors clustered at the session level.

RESULT 4: *Participants form correct beliefs about their groupmates' extraction choices in most treatments, correctly anticipating exploitative behavior will steadily emerge only when restoration is cheap and certain; instead, they tend to slightly over-estimate others' willingness to invest in restoration in all conditions despite correctly capturing level effects across different cost dimensions.*

Table 4: Beliefs about Others' Choices (Round 1), Statistical Tests for ATEs

	Others' Extraction		Others' Restoration	
	Belief	*Bias*	Belief	*Bias*
T2 - Uncertain / Low	3.234**	2.973**	-2.557*	0.276
	(1.260)	(1.238)	(1.503)	(0.765)
T3 - Certain / Low	32.586***	-1.847*		
	(1.839)	(1.006)		
T4 - Uncertain / High	2.426*	1.009	16.648***	0.962
	(1.341)	(0.835)	(3.843)	(1.478)
T5 - Certain / High	1.424***	2.893***	14.840***	1.005
	(0.501)	(0.901)	(1.923)	(1.554)
Constant	40.446***	0.863	24.863***	2.358***
	(0.164)	(0.655)	(0.835)	(0.640)
Observations	1980	1980	1140	1140

Notes. GLS-RE Estimates: an observation is a subject in a round of a supergame. In each column, the dependent variable is a continuous variable measuring: (1) beliefs on the sum of other group members' total extraction choices; (2) the distance between beliefs and actual levels for other group members' total extraction choices; (3) beliefs on the sum of other group members' restoration choices; (4) the distance between beliefs and actual levels for other group members' restoration choices. The baseline treatment in columns 1 and 2 is T1 - Baseline. The baseline treatment in columns 3 and 4 is T3 - Certain / Low. Standard errors clustered at the session level.

6 Conclusion

Our study provides crucial insights into the role of Negative Emission Technologies (NETs) as potential deterrents to mitigation efforts. Indeed, in the most optimistic scenario where these technologies are a certain and cheap option, our experimental communities coordinate on the equilibrium where mitigation is entirely substituted by restoration. Moreover, short-term mitigation decisions are influenced in all scenarios where these technologies are available. The treatments where removal technologies are characterized by high costs and uncertainty (a far more likely scenario outside of the laboratory) result in adverse short-term effects. These include decreased payoffs, heightened inequality, and increased coordination challenges, amplifying especially the impact of defectors and free riders. Even under the most optimistic scenario, carbon removal technologies prove ineffective in prolonging the lifespan of the resource or increasing the welfare of our experimental communities and contribute to greater inequality in earnings, primarily driven by greater dispersion in extraction choices.

Our findings raise concerns about the risks of portraying Negative Emission Technologies as fail-safe and low-cost mechanisms, as this would shift the focus away from the required short-term mitigation. More generally, our results underscore the pivotal role of how information about the characteristics of these technologies will be conveyed. Scientists, policymakers, and the media must navigate the narrative surrounding the affordability and reliability of restoration technologies with care.

In conclusion, our study sheds light on the complexities surrounding integrating restoration technologies in the context of climate change negotiations. Recognizing the limited positive impact on resource longevity and earnings and the critical influence of cost considerations and acknowledging the possibility of irreversible climate change is essential for formulating effective policies and communication strategies. As the global community strives for sustainable solutions, these findings contribute valuable insights to inform future decision-making and action in pursuing a resilient and climate-conscious society.

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Appendix

A Equilibrium Analysis

The following propositions characterize the conditions for existence of all symmetric and stationary SPNEs of the restorable common pool resource game described in Section 2.

Proposition 1 (Extract, Don't Restore) *An equilibrium of the game where, in each period,* $e_i^\star = \frac{K}{n}$ *and* $r_i^\star = 0$ *exists for any* $\delta \in [0,1]$*. In this equilibrium, the resource is exhausted in a single period, and the value of the game is* $V_1^{EQ} = \frac{W+K}{n}$*.*

Proposition 2 (Conserve, Don't Restore) *An equilibrium of the game where, in each period,* $e_i^\star = \frac{T_E}{n}$ *and* $r_i^\star = 0$ *exists if and only if* $\delta \geq \frac{K-T_E}{W+K}$*. In this equilibrium, the resource is never exhausted, and the value of the game is* $V_2^{EQ} = \frac{W+T_E}{n(1-\delta)}$*.*

Proposition 3 (Extract, Restore) *Assume* $\rho > 0$*. An equilibrium of the game where, in each period,* $e_i^\star = \frac{K}{n}$ *and* $r_i^\star = \frac{T_R}{n}$ *exists if and only if* $\delta > \frac{T_R}{W+K}$*. In this equilibrium, the resource is exhausted when the game does not reach the Restoration Phase in a period. Thus, at the beginning of every period, the expected number of periods until the resource is exhausted equals* $1/(1-\rho)$*. The value of the game is* $V_3^{EQ} = \frac{W+K-\rho T_R}{(1-\delta\rho)n}$*.*

Proposition 4 (Conserve, Restore with Uncertain Restoration Technology) *Assume* $\rho \in (0,1)$*. An equilibrium of the game where, in each period,* $e_i^\star = \frac{T_E}{n}$ *and* $r_i^\star = \frac{T_R}{n}$ *exists if and only if* $\delta \geq \max\left\{\frac{K-\rho T_R - T_E}{W+K-\rho(W+T_E+T_R)}, \frac{T_R}{W+T_E+T_R}\right\}$*. In this equilibrium, the resource is never exhausted, and the value of the game is* $V_4^{EQ} = V_2^{EQ} = \frac{W+T_E}{n(1-\delta)}$*.*

Proposition 5 (Conserve, Restore with Certain Restoration Technology) *Assume* $\rho = 1$*. An equilibrium of the game where, in each period,* $e_i^\star = \frac{T_E}{n}$ *and* $r_i^\star = \frac{T_R}{n}$ *exists if and only if* $T_R \geq K - T_E$ *and* $\delta \geq \frac{T_R}{W+T_E+T_R}$*. In this equilibrium, the resource is never exhausted, and the value of the game is* $V_5^{EQ} = V_2^{EQ} = \frac{W+T_E}{n(1-\delta)}$*.*

B Proofs

Proof of Proposition 1

There is no profitable deviation in either phase because, by Assumptions 1 and 2, a player cannot unilaterally avoid the transition to the Restoration Phase when everybody else extracts the largest feasible amount (in the Extraction Phase) and a player cannot unilaterally prevent resource depletion when nobody else makes any restoration effort (in the Restoration Phase).

Proof of Proposition 2

In the Extraction Phase, there is no profitable deviation if and only if:

$$\begin{aligned} V^{EQ} = \frac{W+T_E}{n(1-\delta)} &\geq \frac{W+K}{n} \\ W+T_E &\geq (W+K)(1-\delta) \\ T_E &\geq K-\delta(W+K) \\ \delta &\geq \frac{K-T_E}{W+K} \end{aligned}$$

In the Restoration Phase, there is no profitable deviation because, by Assumptions 2, a player cannot unilaterally avoid exhaustion when nobody else makes any restoration effort.

Proof of Proposition 3

In the Extraction Phase, there is no profitable deviation because, by Assumptions 1, a player cannot unilaterally avoid the transition to the Restoration Phase when everybody else extracts the largest feasible amount. In the Restoration Phase, there is no profitable deviation if and only if:

$$\begin{aligned} -\frac{T_R}{n} + \delta V^{EQ} &\geq 0 \\ \delta V^{EQ} &\geq \frac{T_R}{n} \end{aligned}$$

Since the continuation value of the game under equilibrium strategies is equal to $V^{EQ} = \frac{(W+K)}{n} - \rho\frac{T_R}{n} + \rho\delta V^{EQ}$, we have $V^{EQ} = \frac{(W+K)-\rho T_R}{(1-\delta\rho)n}$ and the condition above becomes

$$\begin{aligned}
\delta\frac{(W+K)-\rho T_R}{(1-\delta\rho)n} &\geq \frac{T_R}{n} \\
\delta(W+K-\rho T_R) &\geq T_R(1-\delta\rho) \\
\delta(W+K) &\geq T_R \\
\delta &\geq \frac{T_R}{(W+K)}
\end{aligned}$$

Proof of Propositions 4 and 5

In the Extraction Phase, there is no profitable deviation if and only if:

$$\begin{aligned}
V^{EQ} &\geq \frac{W+K}{n} - \rho\frac{T_R}{n} + \rho\delta V^{EQ} \\
(1-\rho\delta)V^{EQ} &\geq \frac{W+K}{n} - \rho\frac{T_R}{n}
\end{aligned}$$

Since the continuation value of the game under equilibrium strategies is given by $V^{EQ} = \frac{W+T_E}{n(1-\delta)}$, the condition above becomes

$$\begin{aligned}
(1-\delta\rho)\frac{W+T_E}{n(1-\delta)} &\geq \frac{W+K}{n} - \rho\frac{T_R}{n} \\
\frac{1-\delta\rho}{1-\delta} &\geq \frac{W+K-\rho T_R}{W+T_E}
\end{aligned}$$

When $\rho = 1$, the condition above becomes $T_E \geq K - T_R$.

When $\rho \in (0,1)$, the condition above becomes:

$$\frac{(1-\delta\rho)(W+T_E)-(W+K-\rho T_R)(1-\delta)}{(1-\delta)(W+T_E)} \geq 0$$

Since the denominator of the LHS is always positive, this condition reduces to checking whether the numerator of the LHS is positive, that is,

$$\begin{aligned}
(1-\delta\rho)(W+T_E)-(W+K-\rho T_R)(1-\delta) &\geq 0 \\
W+T_E-\delta\rho(W+T_E)-W-K+\rho T_R+\delta(W+K-\rho T_R) &\geq 0 \\
-\delta\rho(W+T_E)+\delta(W+K-\rho T_R) &\geq K-\rho T_R-T_E \\
\delta(W+K-\rho(W+T_E+T_R)) &\geq K-\rho T_R-T_E \\
\delta &\geq \frac{K-\rho T_R-T_E}{W+K-\rho(W+T_E+T_R)}
\end{aligned}$$

Since the RHS is strictly less than 1, there exists a value of $\delta \in [0,1]$ such that this holds. Thus, when $\rho \in (0,1)$, the condition for no profitable deviation in the Extraction Phase becomes $\delta \geq \frac{K-\rho T_R-T_E}{W+K-\rho(W+T_E+T_R)}$.

In the Restoration Phase, there is no profitable deviation if and only if:

$$\begin{aligned}
-\frac{T_R}{n}+\delta V^{EQ} &\geq 0 \\
-\frac{T_R}{n}+\delta\frac{W+T_E}{n(1-\delta)} &\geq 0 \\
\delta &\geq \frac{T_R}{W+T_E+T_R}
\end{aligned}$$

Since the RHS is strictly less than 1, there exists a value of $\delta \in [0,1]$ such that this holds.

C Robustness Check: All Supergames

As for the analyses reported in the main text, due to some minor and unexpected technical issues, we exclude N=6 groups from the analysis on Block 1 behavior: groups 1,3 from session 3 (T2); group 1 from session 4 (T3); groups 1,2,3 from session 5 (T4).

Table 5: Resource Life & Payoffs (Block 1), Statistical Tests for ATEs

	Pr(Resource Conserved)	Resource Life Length	Round Payoff	Cumulative Payoff
	Group		*Individual*	
T2 - Uncertain / Low	-0.063	-0.486	-0.529***	-15.493*
	(0.051)	(0.312)	(0.143)	(9.266)
T3 - Certain / Low	0.036	0.192	1.380***	12.841
	(0.049)	(0.297)	(0.273)	(8.755)
T4 - Uncertain / High	-0.055	-0.422	-0.736***	-13.282
	(0.071)	(0.435)	(0.156)	(12.524)
T5 - Certain / High	-0.025	-0.067	-1.516***	-6.322
	(0.046)	(0.286)	(0.188)	(8.837)
Constant	0.851***	3.939***	29.900***	116.460***
	(0.046)	(0.263)	(0.084)	(7.906)
Observations	4221	1110	21105	5550
R2-adj		0.019		
R2-overall			0.060	0.038
σ_u	1.253		1.811	15.710
σ_e			3.236	46.996
ρ	0.323		0.238	0.101

Notes. Column 1 reports Average Marginal Effects for the Logit-RE model: an observation is a group in a round of a supergame; Column 2 reports OLS Estimates: an observation is a group in a supergame; Column 3 reports GLS-RE Estimates: an observation is a subject in a round of a supergame; Column 4 reports GLS-RE Estimates: an observation is a subject in a supergame. In each column, the dependent variable is: (1) a dummy variable equal to one if the group manages to conserve the resource, either by not exceeding the extractions limit or by implementing successful restoration actions in each round of Block 1 actually played; (2) a continuous variable measuring resource life length, defined as the number of rounds actually played by each group out of the first 5; (3) a continuous variable measuring individual round payoff, in each round of Block 1 actually played; (4) a continuous variable measuring individual cumulative payoff accrued over all rounds actually played in Block 1. The baseline treatment is T1 - Baseline. Results are based on (round or cumulative) Block 1 evidence in all supergames. Standard errors clustered at the session level.

Table 6: Analysis of Payoffs Dispersion (Block 1), Statistical Tests for ATEs

	Round Payoff SD	Cumulative Payoff	Cum. Extraction SD	Cum. Restoration^{PR} SD	Cum. Payoff SD
T2 - Uncertain / Low	1.644***	3.942***	3.484***	-4.075***	
	(0.576)	(1.250)	(1.223)	(0.721)	
T3 - Certain / Low	2.063***	8.232***	6.207***		
	(0.405)	(1.305)	(1.080)		
T4 - Uncertain / High	1.070*	1.648**	0.520	-3.643***	
	(0.636)	(0.782)	(0.680)	(0.758)	
T5 - Certain / High	1.630***	4.306***	1.928**	-1.575**	
	(0.365)	(0.757)	(0.882)	(0.741)	
Cum. Extraction SD					0.888***
					(0.024)
Cum. Restoration^{PR} SD					0.593***
					(0.081)
Constant	1.239***	3.173***	3.173***	5.373***	0.396
	(0.289)	(0.568)	(0.568)	(0.661)	(0.253)
Observations	4221	1110	1110	798	798
R2-adj (overall)	(0.103)	0.181	0.144	0.165	0.896

Notes. SD: within-group standard deviation. Column 1 reports GLS-RE Estimates: an observation is a group in a round of a supergame; Columns 2-5 report OLS Estimates: an observation is a group in a supergame. In each column, the dependent variable captures dispersion, measured through within-group standard deviation, in: (1) round payoffs in Block 1; (2,5) cumulative payoffs in Block 1; (3) cumulative extraction choices in Block 1; (4) cumulative payoff-relevant restoration choices in Block 1. Restoration choices are payoff-relevant only if restoration is needed because the extraction threshold is exceeded, and available – and otherwise valued as zero. The baseline treatment in columns 1, 2 and 3 is T1 - Baseline. The baseline treatment in column 4 is T3 - Certain / Low. Results are based on cumulative Block 1 evidence from all supergames. Standard errors clustered at the session level.

D Robustness Check: All Rounds & All Supergames

As for the analyses reported in the main text, due to some minor and unexpected technical issues, we exclude $N = 8$ groups from the analysis on Block 1 behavior: groups 1,3 from session 3 (T2); group 1 from session 4 (T3); groups 1,2,3 from session 5 (T4); and groups 1,4 from session 1 (T1), who experienced the glitch while playing rounds belonging to Block 2.

Table 7: Resource Life & Payoffs (All Rounds), Statistical Tests for ATEs

	Pr(Resource Conserved)	Resource Life Length	Round Payoff	Cumulative Payoff
	Group		*Individual*	
T2 - Uncertain / Low	-0.057	-0.597	-0.537***	-19.520
	(0.053)	(0.535)	(0.146)	(16.109)
T3 - Certain / Low	0.033	0.270	1.588***	17.501
	(0.048)	(0.551)	(0.296)	(16.634)
T4 - Uncertain / High	-0.043	-0.404	-0.709***	-13.311
	(0.069)	(0.641)	(0.182)	(19.023)
T5 - Certain / High	-0.021	-0.164	-1.487***	-9.632
	(0.046)	(0.479)	(0.177)	(14.739)
Constant	0.849***	4.648***	29.937***	137.971***
	(0.045)	(0.420)	(0.091)	(12.946)
Observations	4990	1108	24950	5540
R2-adj		0.005		
R2-overall			0.067	0.016
σ_u	1.187		1.816	23.269
σ_e			3.150	91.161
ρ	0.300		0.249	0.061

Notes. Column 1 reports Average Marginal Effects for the Logit-RE model: an observation is a group in a round of a supergame; Column 2 reports OLS Estimates: an observation is a group in a supergame; Column 3 reports GLS-RE Estimates: an observation is a subject in a round of a supergame; Column 4 reports GLS-RE Estimates: an observation is a subject in a supergame. In each column, the dependent variable is: (1) a dummy variable equal to one if the group manages to conserve the resource, either by not exceeding the extractions limit or by implementing successful restoration actions in each round played; (2) a continuous variable measuring resource life length, defined as the number of rounds actually played by each group in a supergame; (3) a continuous variable measuring individual round payoff, in each round played; (4) a continuous variable measuring individual cumulative payoff accrued over all rounds played in a supergame. The baseline treatment is T1 - Baseline. Results are based on (round or cumulative) evidence over all rounds played of all supergames. Standard errors clustered at the session level.

Table 8: Analysis of Payoffs Dispersion (All Rounds), Statistical Tests for ATEs

	Round Payoff SD	Cumulative Payoff	Cum. Extraction SD	Cum. Restoration^{PR} SD	Cum. Payoff SD
T2 - Uncertain / Low	1.625***	4.249***	3.709***	-4.383***	
	(0.574)	(1.252)	(1.220)	(0.865)	
T3 - Certain / Low	1.975***	8.814***	6.509***		
	(0.409)	(1.641)	(1.419)		
T4 - Uncertain / High	1.055*	1.594**	0.376	-4.002***	
	(0.639)	(0.755)	(0.664)	(0.901)	
T5 - Certain / High	1.649***	4.635***	2.078*	-1.657*	
	(0.364)	(0.843)	(1.032)	(0.877)	
Cum. Extraction SD					0.909***
					(0.015)
Cum. Restoration^{PR} SD					0.601***
					(0.066)
Constant	1.264***	3.579***	3.579***	5.833***	0.284*
	(0.293)	(0.543)	(0.543)	(0.819)	(0.139)
Observations	4990	1108	1108	798	798
R2-adj (overall)	(0.091)	0.148	0.110	0.174	0.920

Notes. SD: within-group standard deviation. Column 1 reports GLS-RE Estimates: an observation is a group in a round of a supergame; Columns 2-5 report OLS Estimates: an observation is a group in a supergame. In each column, the dependent variable captures dispersion, measured through within-group standard deviation, in: (1) round payoffs; (2,5) cumulative payoffs; (3) cumulative extraction choices; (4) cumulative payoff-relevant restoration choices. Restoration choices are payoff-relevant only if restoration is needed because the extraction threshold is exceeded, and available – and otherwise valued as zero. The baseline treatment in columns 1, 2 and 3 is T1 - Baseline. The baseline treatment in column 4 is T3 - Certain / Low. Results are based on (round or cumulative) evidence over all rounds played of all supergames. Standard errors clustered at the session level.

E Experience Effects

Table 9: Extraction & Restoration Choices, Round 1: ATEs in Early vs. Late Supergames

	Extraction		Restoration	
	Late: 4+	*Late: 4-6*	*Late: 4+*	*Late: 4-6*
T2 - Uncertain / Low	0.364	0.364	-0.161	-0.161
	(0.288)	(0.288)	(0.319)	(0.319)
T3 - Certain / Low	1.550***	1.550***		
	(0.459)	(0.459)		
T4 - Uncertain / High	0.039	0.039	5.128***	5.128***
	(0.360)	(0.361)	(0.714)	(0.714)
T5 - Certain / High	0.053	0.053	4.286***	4.286***
	(0.283)	(0.283)	(0.685)	(0.685)
I_{LATE}	0.621***	0.522**	0.099	0.219
	(0.217)	(0.217)	(0.183)	(0.182)
T2 $\cdot I_{LATE}$	-0.137	0.069	-0.433	-0.203
	(0.316)	(0.371)	(0.276)	(0.265)
T3 $\cdot I_{LATE}$	6.039***	5.492***		
	(0.538)	(0.551)		
T4 $\cdot I_{LATE}$	0.154	0.072	-1.064**	-0.817**
	(0.278)	(0.262)	(0.430)	(0.326)
T5 $\cdot I_{LATE}$	-0.312	-0.203	-0.831*	-0.750*
	(0.306)	(0.303)	(0.460)	(0.407)
Constant	9.242***	9.242***	5.728***	5.728***
	(0.214)	(0.214)	(0.244)	(0.244)
Observations	5580	3600	4020	2880
R2-overall	0.376	0.309	0.141	0.150
σ_u	1.923	1.975	4.149	4.141
σ_e	2.381	2.582	3.482	3.428
ρ	0.395	0.369	0.587	0.593

Notes. GLS-RE estimates: an observation is a subject in a supergame. In each column, the dependent variable is a continuous variable measuring individual extraction (1-2) and restoration (3-4) choices. The baseline treatment in columns 1 and 2 is T1 - Baseline. The baseline treatment in columns 3 and 4 is T3 - Certain / Low. I_{LATE} is a dummy variable equal to one for supergames 4+. Results are based on Round 1 behavior in all supergames (columns 1 and 3) and in supergames 4-6 only (columns 2 and 4). Standard errors clustered at the session level.

F Effect of Eliciting Beliefs on Behavior

Table 10: Before vs. After Beliefs' Elicitation, Round 1 Choices, Statistical Tests for ATEs

	Extraction		Restoration	
	1-6 vs. 7+	*5-6 vs. 7-8*	*1-6 vs. 7+*	*5-6 vs. 7-8*
T2 - Uncertain / Low	0.399*	0.429	-0.262	-0.263
	(0.206)	(0.346)	(0.286)	(0.342)
T3 - Certain / Low	4.296***	7.721***		
	(0.566)	(0.671)		
T4 - Uncertain / High	0.075	0.062	4.719***	4.121***
	(0.313)	(0.327)	(0.767)	(0.897)
T5 - Certain / High	-0.049	-0.138	3.911***	3.392***
	(0.160)	(0.176)	(0.678)	(0.729)
I_{AFTER}	0.405**	-0.025	-0.244**	-0.306***
	(0.196)	(0.131)	(0.120)	(0.118)
$T2 \cdot I_{AFTER}$	-0.334	-0.309	-0.487*	-0.328
	(0.219)	(0.271)	(0.257)	(0.224)
$T3 \cdot I_{AFTER}$	4.497***	0.853**		
	(0.640)	(0.427)		
$T4 \cdot I_{AFTER}$	0.286	0.217	-0.844*	0.023
	(0.274)	(0.162)	(0.445)	(0.293)
$T5 \cdot I_{AFTER}$	-0.270	-0.148	-0.517	0.342
	(0.233)	(0.156)	(0.667)	(0.482)
Constant	9.503***	9.833***	5.837***	5.938***
	(0.129)	(0.137)	(0.159)	(0.093)
Observations	5580	2240	4020	1760
R2-overall	0.299	0.546	0.142	0.117
σ_u	1.886	2.367	4.149	4.822
σ_e	2.631	1.707	3.477	2.867
ρ	0.339	0.658	0.587	0.739

Notes. GLS-RE Estimates: an observation is a subject in a round. In each column, the dependent variable is: (1)-(2) a continuous variable measuring individual extraction choices in Round 1; (3)-(4) a continuous variable measuring individual restoration choices in Round 1; I_{AFTER} is a dummy variable equal to one if the observation is collected starting from the 7^{th} supergame onwards. The baseline treatment in columns 1 and 2 is T1 - Baseline. The baseline treatment in columns 3 and 4 is T3 - Certain / Low. Standard errors clustered at the session level.

G Additional Tables

Table 11: Number of Supergames in Session, Summary Statistics

	Observations	Mean	Std. Dev.	Min	Max
T1 - Baseline	6	13	2.97	10	18
T2 - Uncertain / Low	6	9	1.67	6	11
T3 - Certain / Low	6	7.67	1.21	7	10
T4 - Uncertain / High	6	8.67	0.82	8	10
T5 - Certain / High	6	8.17	1.17	7	10

Notes. An observation is a session: each session counts 20 participants and includes 60 minutes of play. The number of supergames played within a session statistically differs from the T1 - Baseline in all treatments with Restoration. Non-parametric Wilcoxon (Mann–Whitney) test statistics (exact p-values): *T1 vs. T2* z-stat = 2.441 (0.0130); *T1 vs. T3* z-stat = 2.797 (0.0065); *T1 vs. T4* z-stat = 2.771 (0.0065); *T1 vs. T5* z-stat = 2.756 (0.0065). Non-parametric Kruskal-Wallis test: including all treatments $\chi^2 = 15.026$ (0.0046); excluding T1 - Baseline $\chi^2 = 4.337$ (0.2273).

Table 12: Share of Correctly Answered Comprehension Questions, Summary Statistics

	a. First attempt				
	Observations	Mean	Std. Dev.	Min	Max
T1 - Baseline	120	2.54	0.62	1	3
T2 - Uncertain / Low	120	2.02	0.88	0	3
T3 - Certain / Low	120	2.28	0.83	0	3
T4 - Uncertain / High	120	2.11	0.85	0	3
T5 - Certain / High	120	2.3	0.84	0	3
	b. Second attempt				
	Observations	Mean	Std. Dev.	Min	Max
T1 - Baseline	47	2.79	0.46	1	3
T2 - Uncertain / Low	80	2.6	0.57	1	3
T3 - Certain / Low	62	2.69	0.56	1	3
T4 - Uncertain / High	73	2.58	0.58	1	3
T5 - Certain / High	58	2.67	0.54	1	3

Notes. An observation is a subject. In all treatment conditions, subjects must answer three comprehension questions: the questions are always the same, and the correct answers to the latter are treatment-specific. Subjects have two attempts to answer the questions before moving to the game stage: *Panel a* shows the share of correctly answered questions after subjects' first attempt; *Panel b* shows the share of correctly answered questions for subjects who engage in the second attempt, after failing to answer all questions correctly in the first attempt. The share of correctly answered questions is statistically different from the Baseline in all treatments with Restoration at the end of the first attempt. In all treatments with restoration, the share of correctly answered questions is lower, and this difference is stronger if the availability of restoration technologies is uncertain (irrespective of restoration costs). Non-parametric Kruskal-Wallis equality-of-populations rank test statistic (p-value): 28.113 (0.001). Mann-Whitney-Wilcoxon test statistics on equality of medians (p-values): *T1 vs. T2* z-stat = 4.891 (0.000); *T1 vs. T3* z-stat = 2.330 (0.0198); *T1 vs. T4* z-stat = 4.092 (0.000); *T1 vs. T5* z-stat = 2.050 (0.0404). The share of correctly answered questions for subjects who engage in the second attempt is not statistically different across treatments. Non-parametric Kruskal-Wallis equality-of-populations rank test statistic (p-value): 6.438 (0.1688).

Table 13: Extraction & Restoration Choices (Round 1), Statistical Tests for ATEs

	Extraction Choice	Pr(Excessive Group Extraction)	Restoration Choice	Pr(Sufficient Group Restoration)
T2 - Uncertain / Low	0.209	0.200**	-0.564*	-0.226**
	(0.185)	(0.082)	(0.305)	(0.091)
T3 - Certain / Low	7.544***	0.807***		
	(0.612)	(0.054)		
T4 - Uncertain / High	0.194	0.112	4.088***	-0.757***
	(0.383)	(0.123)	(0.953)	(0.057)
T5 - Certain / High	-0.274**	-0.030	3.463***	-0.790***
	(0.138)	(0.063)	(0.653)	(0.030)
Constant	9.857***	0.175***	5.828***	0.830***
	(0.098)	(0.051)	(0.079)	(0.026)
Observations	3780	756	2580	516

Notes. Columns 1 and 3 report GLS-RE estimates: an observation is a subject in a supergame. Columns 2 and 4 report Average Marginal Effects for Logit models: an observation is a group in a supergame. In each column, the dependent variable is: (1) a continuous variable measuring individual extraction choice; (2) a dummy equal to one if the group extraction threshold is exceeded; (3) a continuous variable measuring individual restoration choice; (4) a dummy equal to one if the group effort is sufficient for restoration irrespective of whether restoration is needed and available. The baseline treatment in columns 1 and 2 is T1. The baseline treatment in columns 3 and 4 is T3. Standard errors clustered at the session level.

Table 14: Summary Statistics on Resource Restoration, Round 1

		Restoration Effort Sufficient $\sum r_i \geq T_R$			Restoration Successful $\sum r_i \geq T_R$ & Restoration available
		Overall	*ELE=0*	*ELE=1*	
T2 - Uncertain / Low	%	60.42	63.3	55.56	37
	N	144	90	54	54
T3 - Certain / Low	%	83	100	82.73	82.73
	N	112	2	110	110
T4 - Uncertain / High	%	7.35	7	7.69	5
	N	136	97	39	39
T5 - Certain / High	%	4	3.77	5.55	5.55
	N	124	106	18	18

Notes. An observation is a group in the first round of a supergame. The restoration effort is sufficient if group restoration efforts are equal to or greater than the treatment-specific threshold ($\sum r_i \geq T_R$). ELE=0 is the subsample of observations in which the extraction limit is not exceeded; hence, there is no need for restoration (because total group extraction was below the threshold, $\sum e_i \leq T_E$), while ELE=1 is the subsample of observations in which extraction limit is exceeded in the first stage, hence restoration is needed (because group extraction was above the threshold). Restoration is successful if restoration efforts meet the threshold when needed (ELE=1) and the technology is available.

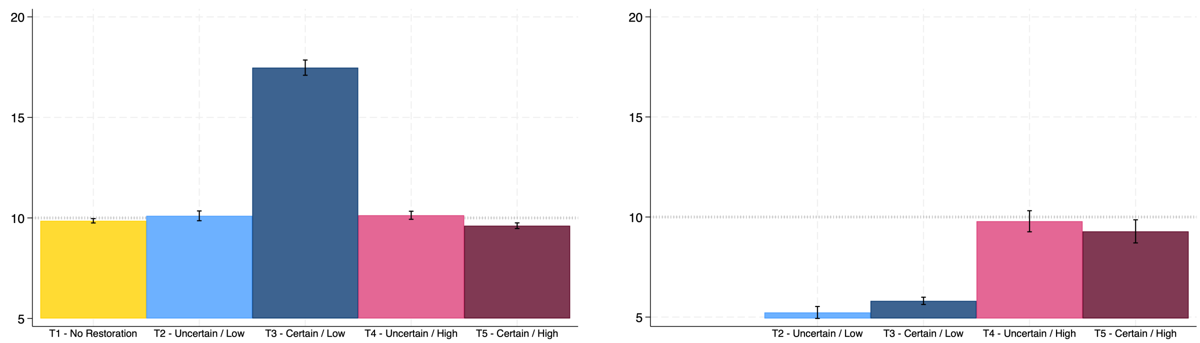
Table 15: Resource Life & Payoffs (Block 1), Statistical Tests for ATEs

	Pr(Resource Conserved)	Resource Life Length	Round Payoff	Cumulative Payoff
T2 - Uncertain / Low	-0.070	-0.545	-0.504***	-17.021*
	(0.054)	(0.338)	(0.135)	(9.918)
T3 - Certain / Low	-0.005	-0.044	2.865***	11.844
	(0.051)	(0.306)	(0.374)	(9.115)
T4 - Uncertain / High	-0.068	-0.558	-0.728***	-16.276
	(0.080)	(0.488)	(0.196)	(14.104)
T5 - Certain / High	-0.026	-0.049	-1.365***	-4.289
	(0.048)	(0.329)	(0.245)	(10.292)
Constant	0.866***	4.017***	29.996***	118.942***
	(0.044)	(0.258)	(0.079)	(7.900)
Observations	2867	750	14335	3750

Notes. Column 1 reports Average Marginal Effects for the Logit-RE model: an observation is a group in a round of a supergame; Column 2 reports OLS Estimates: an observation is a group in a supergame; Column 3 reports GLS-RE Estimates: observation is a subject in a round of a supergame; Column 4 reports GLS-RE Estimates: observation is a subject in a supergame. In each column, the dependent variable is: (1) a dummy variable equal to one if the group manages to conserve the resource, either by not exceeding the extraction threshold or by successful restoration; (2) a continuous variable measuring the number of rounds the resource was conserved in; (3) a continuous variable measuring individual round payoff; (4) a continuous variable measuring individual cumulative payoff accrued over Rounds 1-5. The baseline treatment is T1. Standard errors clustered at the session level.

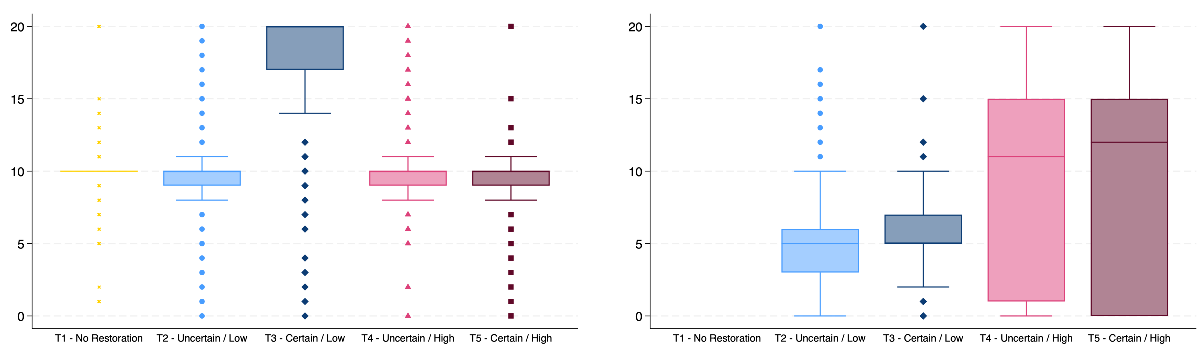
H Additional Figures

Figure 9: Mean Individual Extraction and Restoration Choices, Round 1



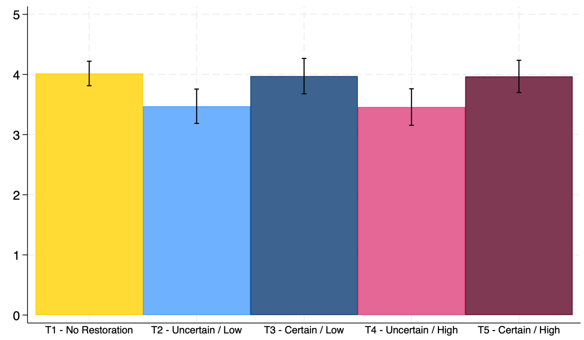
Notes. Mean values: whiskers denote 95% confidence intervals. *Left panel*: Extraction choices: Mann-Whitney-Wilcoxon test statistics on equality of medians (p-values): *T1 vs. T2* z-stat=−1.358 (0.175); *T1 vs. T3* z-stat=−27.675 (0.000); *T1 vs. T4* z-stat= 1.059 (0.290); *T1 vs. T5* z-stat= 1.589 (0.112). Kolgomorov-Smirnov test statistics on equality of distributions (p-values): *T1 vs. T2* D=0.0892 (0.002); *T1 vs. T3* D=0.7614 (0.000); *T1 vs. T4* D=0.0451(0.339); *T1 vs. T5* D=0.0549 (0.169). *Right panel*: Restoration choices: Mann-Whitney-Wilcoxon test statistics on equality of medians (p-values): *T3 vs. T2* z-stat=−6.404 (0.000); *T3 vs. T4* z-stat=−10.299 (0.000); *T3 vs. T5* z-stat=−7.493 (0.000). Kolgomorov-Smirnov test statistics on equality of distributions (p-values): *T3 vs. T2* D=0.1837 (0.000); *T3 vs. T4* D=0.5387 (0.000); *T3 vs. T5* D=0.5212 (0.000).

Figure 10: Box Plots of Individual Extraction and Restoration Choices, Round 1



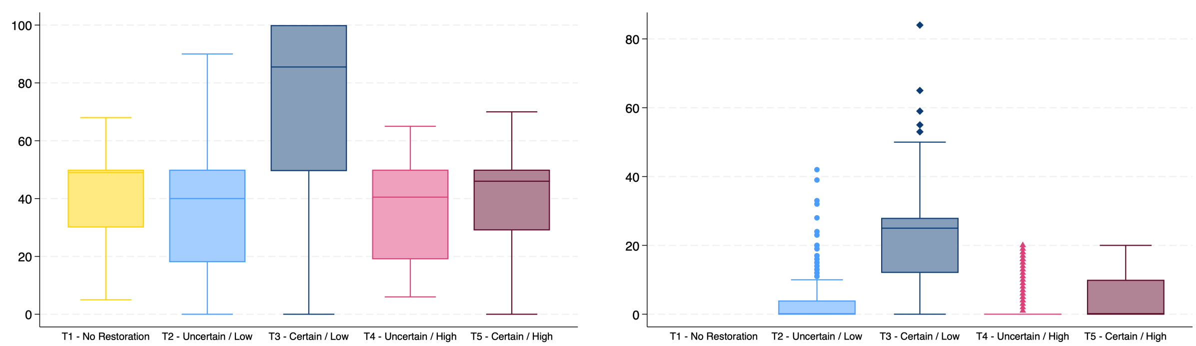
Notes. Box plots: the line inside the box denotes the median, while the upper and lower borders of the box indicate the 75th and 25th percentiles of the distribution, respectively. Whiskers' ends identify the furthest observations within one and a half interquartile range of the upper/lower ends of the box. Points marked outside of the box and whiskers correspond to outside values. *Left panel*: Extraction choices; *Right panel*: Restoration choices.

Figure 11: Resource Life Length: Block 1 (Rounds 1-5)



Notes. Mean values: whiskers denote 95% confidence intervals. Mann-Whitney-Wilcoxon test statistics on equality of medians (p-values): *T1 vs. T2* z-stat=3.506 (0.0005); *T1 vs. T3* z-stat=0.712 (0.4765); *T1 vs. T4* z-stat=3.278 (0.0010); *T1 vs. T5* z-stat=0.766 (0.4437). Kolgomorov-Smirnov test statistics on equality of distributions (p-values): *T1 vs. T2* D=0.2029 (0.001); *T1 vs. T3* D=0.0562 (0.970); *T1 vs. T4* D=0.1770 (0.009); *T1 vs. T5* D=0.0668 (0.859).

Figure 12: Box Plots of Cumulative Extraction and Restoration Choices in Block 1



Notes. Box plots: the line inside the box denotes the median, while the upper and lower borders of the box indicate the 75th and 25th percentiles of the distribution, respectively. Whiskers' ends identify the furthest observations within one and a half interquartile range of the upper/lower ends of the box. Points marked outside of the box and whiskers correspond to outside values. *Left panel*: Cumulative individual extractions in Rounds 1-5. *Right panel*: Cumulative payoff-relevant individual restoration actions in Block 1. Restoration actions are payoff-relevant if the extraction limit is exceeded and restoration technologies are available.

I Robustness Check: Inequality using Gini Indicators

Table 16: Analysis of Payoffs Dispersion (Block 1), Statistical Tests for ATEs

	Round Payoff *Gini*	Cumulative Payoff *Gini*	Cum. Extraction *Gini*	Cum. Restoration^{PR} *Gini*	Cum. Payoff *Gini*
T2 - Uncertain / Low	0.027***	0.024***	0.053**	-0.017	
	(0.010)	(0.009)	(0.024)	(0.025)	
T3 - Certain / Low	0.031***	0.027***	0.019		
	(0.006)	(0.006)	(0.013)		
T4 - Uncertain / High	0.027*	0.033*	0.016	-0.023	
	(0.016)	(0.019)	(0.022)	(0.042)	
T5 - Certain / High	0.037***	0.036***	0.019	0.123***	
	(0.008)	(0.009)	(0.015)	(0.041)	
Cum. Extraction *Gini*					0.392***
					(0.054)
Cum. Restoration^{PR} *Gini*					0.093***
					(0.018)
Constant	0.015***	0.014***	0.042***	0.135***	0.003
	(0.004)	(0.004)	(0.011)	(0.015)	(0.003)
Observations	2867	750	750	510	510
R2-adj (overall)	(0.081)	0.096	0.078	0.073	0.486

Notes. Gini: within-group Gini indicator. Column 1 reports GLS-RE Estimates: an observation is a group in a round of a supergame; Columns 2-5 report OLS Estimates: an observation is a group in a supergame. In each column, the dependent variable captures dispersion, measured through within-group Gini indicators, in: (1) round payoffs; (2,5) cumulative payoffs; (3) cumulative extraction choices; (4) cumulative payoff-relevant restoration choices. Restoration choices are payoff-relevant only if restoration is needed because the extraction threshold is exceeded, and available – and otherwise valued as zero. The baseline treatment in columns 1, 2 and 3 is T1 - Baseline. The baseline treatment in column 4 is T3 - Certain / Low. Results are based on cumulative Block 1 evidence, from supergames 4+ (experienced subjects). Standard errors clustered at the session level.

J Experimental Instructions

Welcome!

You will earn **7.5 Euros** for showing up on time and completing the experiment.
In addition, you will earn "Experimental Points" (EPs) depending both on your choices, other participants' choices and chance.
The **EPs you earn will be exchanged to euros** at the rate of **0.10 Euros (10 cents) Euros per EP**.

This experiment is divided into **two parts**: each part of the experiment will generate points that count towards your final payoff. You will now read the instructions for the first part. Once this part is over, you will see the instructions for the next part. Your decisions in this part have no influence on the other parts.

Please read instructions carefully!

After the instructions, we will ask you questions to check that you understand how the experiment works.
You should be able to answer all these questions correctly.
You will not be able to participate in the experiment before you answer all questions correctly.

Next

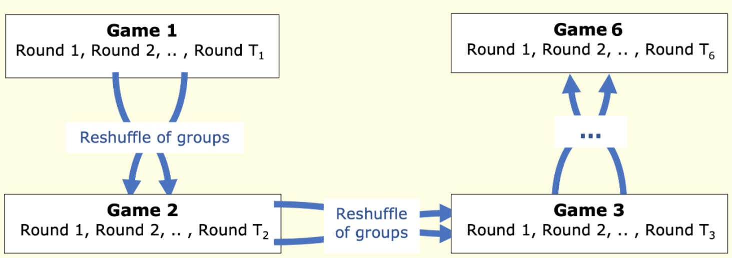
Instructions - PART 1

In this experiment, you will play a sequence of games in groups.

Before each game starts, you will be given an anonymous ID label and **assigned to a group of 5 (including you) randomly selected participants for today's experiment**.

Each game will last for a variable number of rounds.
Groups and ID labels will be fixed over the entire duration of a game.
Once a game is over and a new game begins, you will be given a new anonymous ID label assigned to a new group of 5 randomly selected participants.

PART 1 **will last 6 games**:
- **One game** will be **randomly selected for payment**: your total earnings from PART 1 will be equal to the sum of all Experimental Points (EPs) you gained in this game
- You will learn which game has been randomly selected for payment at the end of the experiment



Next

Instructions - PART 1

AT THE BEGINNING OF EACH GAME, you and your (newly re-shuffled) group mates have access to a **common resource**, which is passed from each round to the next and produces benefits for **all members of the group**.
In every round of a game, all group members receive a private endowment and have the chance to take part of the common resource for their own individual benefit:
- **you and your group mates will decide how many resource units you want to take out** from the common resource
- your **round-earnings** are given by the **sum of your private endowment and the units you take out** of the common resource

WITHIN EACH GAME, the common resource regenerates from round to round as long as you and your group mates do not take out too many units, causing the resource to exhaust and the game to end.

Hence, your take-out decision affects both your round earnings and potential earnings of all members of your group in subsequent rounds.

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Treatment T1: No Restoration

Instructions - PART 1

When each new game starts with the common resource counts **100 units**.

WHAT HAPPENS IN A ROUND?

In every round, everyone in the group gets a private **endowment of 20 units** and can additionally **TAKE OUT any amount between 0 and 20 units** from the resource, to increase own private earnings.

- **If your group takes out more than 50 units:**
  The resource is exhausted and the game **ENDS**
- **If your group takes out between 0 and 50 units:**
  The resource fully regenerates and the game can **CONTINUE** to the next round

Hence, based on total group take-out decisions, **the resource either suddenly collapses, leading to its permanent exhaustion** (if the 50 units limit is exceeded), **or fully replenishes, regrowing to its initial level** (if the limit is not exceeded).

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<u>Treatment T2: Uncertain & Low-Cost Restoration</u>

Instructions - PART 1

When each new game starts with the common resource counts **100 units**.

WHAT HAPPENS IN A ROUND?

In every round, everyone in the group gets a private **endowment of 20 units** and can additionally **TAKE OUT any amount between 0 and 20 units** from the resource, to increase own private earnings.

- **If your group takes out more than <u>50 units</u>:**
  The resource is exhausted and the game **ENDS**
- **If your group takes out between 0 and <u>50 units</u>:**
  The resource fully regenerates and the game can **CONTINUE** to the next round

Hence, based on total group take-out decisions, **the resource either suddenly collapses, leading to its permanent exhaustion** (if the 50 units limit is exceeded), **or fully replenishes, regrowing to its initial level** (if the limit is not exceeded).

In the event your group exceeds the take-out limit, the availability of **restoration technologies may allow your group to make exhaustion reversible.** Restoration technologies allow you and your groupmates to **give up part of your private endowment, and INVEST between 0 and 20 units to restore the common resource.** If the group total restoration effort is high enough, the resource avoids exhaustion and fully regenerates before the next round, as if the take-out limit was not exceeded.

- **If your group, in total, invests less than <u>25 units</u>**:
The resource is not restored and the game **ENDS**
- **If your group, in total, invests <u>25 units</u> or more**:
The resource is restored and fully regenerates and the game can **CONTINUE** to the next ROUND.

Restoration technologies are still in their trial phase: conditional on reaching the target investment needed (25 units), **restoration technologies have a 50% probability to be ready for implementation and effectve in restoring the resource.**
After all group members have made their take-out decision, a restoration phase follows where all group members make their restoration investment decision, before the round ends. You will learn if restoration technologies are ready for implementation and effective only afterward, once the round is over.
The amount of units invested will be deducted from your private endowment only if a restoration action is needed, due to total group extractions exceeding the limit, and if restoration technologies are actually available and ready for implementation.

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Treatment T3: Certain & Low-Cost Restoration

Instructions - PART 1

When each new game starts with the common resource counts **100 units**.

WHAT HAPPENS IN A ROUND?

In every round, everyone in the group gets a private **endowment of 20 units** and can additionally **TAKE OUT any amount between 0 and 20 units** from the resource, to increase own private earnings.

- **If your group takes out more than 50 units:**
  The resource is exhausted and the game **ENDS**
- **If your group takes out between 0 and 50 units:**
  The resource fully regenerates and the game can **CONTINUE** to the next round

Hence, based on total group take-out decisions, **the resource either suddenly collapses, leading to its permanent exhaustion** (if the 50 units limit is exceeded), **or fully replenishes, regrowing to its initial level** (if the limit is not exceeded).

In the event your group exceeds the take-out limit, the availability of **restoration technologies may allow your group to make exhaustion reversible.** Restoration technologies allow you and your groupmates to **give up part of your private endowment, and INVEST between 0 and 20 units to restore the common resource**. If the group total restoration effort is high enough, the resource avoids exhaustion and fully regenerates before the next round, as if the take-out limit was not exceeded.

- **If your group, in total, invests less than 25 units**:
  The resource is not restored and the game **ENDS**
- **If your group, in total, invests 25 units or more**:
  The resource is restored and fully regenerates and the game can **CONTINUE** to the next ROUND.

Restoration technologies are still in their trial phase: conditional on reaching the target investment needed (25 units), **restoration technologies have a 50% probability to be ready for implementation and effectve in restoring the resource.**
After all group members have made their take-out decision, a restoration phase follows where all group members make their restoration investment decision, before the round ends. You will learn if restoration technologies are ready for implementation and effective only afterward, once the round is over.
The amount of units invested will be deducted from your private endowment only if a restoration action is needed, due to total group extractions exceeding the limit, and if restoration technologies are actually available and ready for implementation.

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Treatment T4: Uncertain & High-Cost Restoration

Instructions - PART 1

When each new game starts with the common resource counts **100 units**.

WHAT HAPPENS IN A ROUND?

In every round, everyone in the group gets a private **endowment of 20 units** and can additionally **TAKE OUT any amount between 0 and 20 units** from the resource, to increase own private earnings.

- **If your group takes out more than 50 units:**
  The resource is exhausted and the game **ENDS**
- **If your group takes out between 0 and 50 units:**
  The resource fully regenerates and the game can **CONTINUE** to the next round

Hence, based on total group take-out decisions, **the resource either suddenly collapses, leading to its permanent exhaustion** (if the 50 units limit is exceeded), **or fully replenishes, regrowing to its initial level** (if the limit is not exceeded).

In the event your group exceeds the take-out limit, the availability of **restoration technologies may allow your group to make exhaustion reversible.** Restoration technologies allow you and your groupmates to **give up part of your private endowment, and INVEST between 0 and 20 units to restore the common resource**. If the group total restoration effort is high enough, the resource avoids exhaustion and fully regenerates before the next round, as if the take-out limit was not exceeded.

- **If your group, in total, invests less than 25 units**:
The resource is not restored and the game **ENDS**
- **If your group, in total, invests 25 units or more**:
The resource is restored and fully regenerates and the game can **CONTINUE** to the next ROUND.

Restoration technologies are still in their trial phase: conditional on reaching the target investment needed (25 units), **restoration technologies have a 50% probability to be ready for implementation and effectve in restoring the resource.**
After all group members have made their take-out decision, a restoration phase follows where all group members make their restoration investment decision, before the round ends. You will learn if restoration technologies are ready for implementation and effective only afterward, once the round is over.
The amount of units invested will be deducted from your private endowment only if a restoration action is needed, due to total group extractions exceeding the limit, and if restoration technologies are actually available and ready for implementation.

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Treatment T5: Certain & High-Cost Restoration

Instructions - PART 1

When each new game starts with the common resource counts **100 units**.

WHAT HAPPENS IN A ROUND?

In every round, everyone in the group gets a private **endowment of 20 units** and can additionally **TAKE OUT any amount between 0 and 20 units** from the resource, to increase own private earnings.

- **If your group takes out more than 50 units:**
  The resource is exhausted and the game **ENDS**
- **If your group takes out between 0 and 50 units:**
  The resource fully regenerates and the game can **CONTINUE** to the next round

Hence, based on total group take-out decisions, **the resource either suddenly collapses, leading to its permanent exhaustion** (if the 50 units limit is exceeded), **or fully replenishes, regrowing to its initial level** (if the limit is not exceeded).

In the event your group exceeds the take-out limit, the availability of **restoration technologies may allow your group to make exhaustion reversible.** Restoration technologies allow you and your groupmates to **give up part of your private endowment, and INVEST between 0 and 20 units to restore the common resource**. If the group total restoration effort is high enough, the resource avoids exhaustion and fully regenerates before the next round, as if the take-out limit was not exceeded.

- **If your group, in total, invests less than 25 units**:
  The resource is not restored and the game **ENDS**
- **If your group, in total, invests 25 units or more**:
  The resource is restored and fully regenerates and the game can **CONTINUE** to the next ROUND.

Restoration technologies are still in their trial phase: conditional on reaching the target investment needed (25 units), **restoration technologies have a 50% probability to be ready for implementation and effectve in restoring the resource.**
After all group members have made their take-out decision, a restoration phase follows where all group members make their restoration investment decision, before the round ends. You will learn if restoration technologies are ready for implementation and effective only afterward, once the round is over.
The amount of units invested will be deducted from your private endowment only if a restoration action is needed, due to total group extractions exceeding the limit, and if restoration technologies are actually available and ready for implementation.

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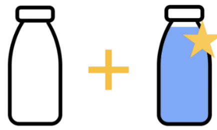
Instructions - PART 1

EXAMPLE

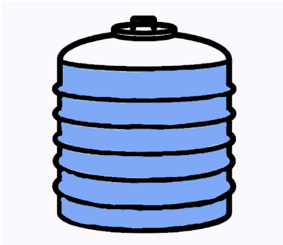
You can picture the common resource as a **water tank**, from which you and your groupmates can take any quantity of water up to your **bottle**'s maximum capacity.

In each round, all group members receive an **endowment** corresponding to a "bonus bottle" filled with 20 liters of water and another empty bottle with 20 liters of capacity.

Each group member can fill the empty bottle at their own convenience, up to its maximum capacity: all liters of water taken are sum up to the 20 liters obtained as endowment and constitute private earnings.



After all members make their choices, if too little water is left in the tank, the game ends.



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Instructions - PART 1

HOW MANY ROUNDS IN EACH GAME?

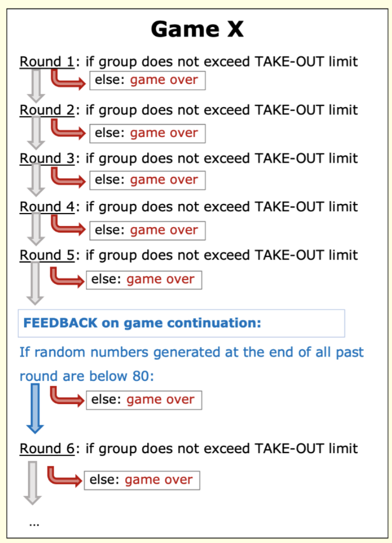
The length of a game (i.e. the number of rounds in a game) depends both on your group choices and chance:

■ If your group exhausts the resource, exceeding the TAKE-OUT limit the **game is over**
You will get feedback on your group choices - hence, on the resource status – at the end of each round

■ If your group conserves the resource, either by not exceeding the TAKE-OUT limit , there is an **80% probability that the game continues for at least another round** and a 20% probability that the game ends. Specifically, at the end of each round in which your group conserves the resource, the computer generates a random number between 1 and 100: if the number is **lower or equal to 80** the game continues for at least another round; if, instead, the number is **above 80** the game ends.

For example, if you are in round 2 and your group conserves the resource in this round, the probability that there will be a 3rd round is 80%. If you are in round 9 and your group conserves the resource in this round, the probability that there will be a 10th round is also 80%. That is, at any point in a game, the probability that it will continue (if your group does not exhaust the resource with its choices) is 80%.

You will get feedback on whether the game continues for another round or not, based on the random numbers generated by the computer, every five rounds, or as soon as the resource is exhausted.
This means that, as long as your group conserves the resource, **you will make choices without knowing whether or not the game ended at some point before the feedback on game continuation is displayed.**
You will only receive earnings for rounds played before the game ended.



To summarize, the **final round of each game** is either the first round in which the random number generated by the computer is greater than 80 or the first round in which your group choices cause resource exhaustion, **whatever comes first**.

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Instructions - PART 1

HOW MANY ROUNDS IN EACH GAME?
Examples

(1) Imagine your group exhausted the resource in the 1st round. You will then see a screen similar to the one below, displaying what rounds matter for payment, based on the random numbers generated by the computer:

R1	R2	R3	R4	R5
40				

HOW MANY ROUNDS WOULD YOU PLAY IN THIS GAME?
Only 1. No additional rounds will be played because the resource was exhausted in round 1

FOR HOW MANY ROUNDS WOULD YOU GET PAID?
For the 1st (and only) round played, for a total of 40 points. The first round of each game always matter for payment. The computer starts generating random numbers to determine whether the game continues or not to a further round only at the end of the first round.

(2) Imagine your group conserved the resource in the first three rounds and exhausted it in the 4th round. You will then see a screen like the one below, displaying your payoffs over rounds and the information on what rounds matter for payment:

R1	R2	R3	R4	R5
20	20	20	40	

R1	R2	R3	R4	R5
47	39	85		
✅	✅	✅	❌	

HOW MANY ROUNDS WOULD YOU PLAY IN THIS GAME?
4 rounds. There will be no 5th round and no additional rounds because the resource was exhausted.

FOR HOW MANY ROUNDS WOULD YOU GET PAID?
Based on the random numbers, only the first 3 rounds matter for payment: my earnings from this game are equal to the sum of earnings accrued over the first 3 rounds of the game, for a total of 60 points.

(3) Imagine your group conserved the resource until the 5th round. You will then see a screen similar to the one below:

R1	R2	R3	R4	R5
20	20	20	20	20

R1	R2	R3	R4	R5	GAME CONTINUES
67	33	35	73	59	
✅	✅	✅	✅	✅	✅

HOW MANY ROUNDS WOULD YOU PLAY IN THIS GAME?
Not sure but at least 6: 5 rounds have already been played and there will be at least another one.

FOR HOW MANY ROUNDS WOULD YOU GET PAID?
Not sure but at least 6: all the 5 rounds played up to this point matter for payment (hence I will earn at least 100 points) and also the next round to be played will matter for payment, as the game continues. At the end of the 10th round or as soon as the resource is exhausted, I will learn whether rounds from the 7th onwards also matter for payment and if the game continues for more than 10 rounds.

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Treatment T1: No Restoration

Instructions - PART 2

The basic structure of this part is **very similar to PART 1**.
Your choice set, how the game proceeds and how you are paired with others will remain the same.

However, **in this part**, you will have **one more task**: at the end of each round, after you make your choice, we will ask you to **submit your belief about the choice of your groupmates**.

To indicate your belief, you will use a slider, ranging between 0 and 80.
Where you **move your slider will represent your best assessment** concerning:
• How many units **YOU THINK your other 4 groupmates TOOK OUT** of the common resource, in total

To determine **your payment in PART 2**, **two games will be randomly selected**, out of all those played
- For **one of these**, you will receive the points associated with your choices as in PART 1
- For **the other**, your payment will depend on the accuracy of your stated beliefs:
  your belief in one (randomly selected) round from that game will determine your chance of winning a prize of 30 points
  ▶ The computer will randomly draw two numbers, between 0 and 80. For each draw, all numbers are equally likely to be selected and draws are independent, in the sense that the outcome of the first draw in no way affects the outcome of the second draw.
  ▶ If your stated belief in that round is closer to your groupmates' choice than either of the two draws, you will win the prize.
- You will learn which games have been randomly selected for payment at the end of the experiment

The **first game to end after 60 minutes of play** (including PART 1) will mark the **end of the experiment**.

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Treatments with Restoration (T2-T5)

Instructions - PART 2

The basic structure of this part is **very similar to PART 1**.
Your choice set, how the game proceeds and how you are paired with others will remain the same.

However, **in this part**, you will have **one more task**: at the end of each round, after you make your choices, we will ask you to **submit your belief about the choices of your groupmates**.

To indicate your belief, you will use two sliders, ranging between 0 and 80.
Where you **move your sliders will represent your best assessment** concerning:
- How many units **YOU THINK your other 4 groupmates TOOK OUT** of the common resource, in total
- How many units **YOU THINK your other 4 groupmates INVESTED** in restoration technologies, in total

To determine **your payment in PART 2**, **two games will be randomly selected**, out of all those played
- For **one of these**, you will receive the points associated with your choices as in PART 1
- For **the other**, your payment will depend on the accuracy of your stated beliefs:
your beliefs in one (randomly selected) round from that game will determine your chance of winning a prize of 30 points
  - ▶ The computer will randomly draw two numbers, between 0 and 80. For each draw, all numbers are equally likely to be selected and draws are independent, in the sense that the outcome of the first draw in no way affects the outcome of the second draw.
  - ▶ If your stated belief in that round is closer to your groupmates' choice than either of the two draws, you will win the prize.
- You will learn which games have been randomly selected for payment at the end of the experiment

The **first game to end after 60 minutes of play** (including PART 1) will mark the **end of the experiment**.

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